# Abstracts

<1>
Ackefors, H., III. Effects of Particular Pollutants. Mercury Pollution in Sweden with Special Reference to Conditions in the Water Habitat., Proc. Roy. Soc. Lond. B., 177: 365-387 (1971).

Highlighted literature is concerned with mercury pollution in Sweden. Specific sections are: mercury compounds; toxicological evaluations; sources of contamination; levels in terrestrial wildlife, and food; levels and accumulation in fish and aquatic organisms; effects of intake in man; and methylation of inorganic mercury.
REVIEW; MERCURY; TOXICOLOGY; HUMAN; ANIMAL

<2>
Anas, R.E., Heavy Metals in the Northern Fur Seal, CALLORHINUS URSINUS, and Harbor Seal, PHOCA VITULINA RICHARDI., Fish. Bull., 71(1): 133-137 (1974)., California; Oregon; Washington; Pribilof Is.

Samples of liver and, in some instances, muscle and kidney from fur seals from the Pribilof Islands as well as Washington and harbor seals from all along the U.S. Pacific coast and the Bering Sea were analyzed by atomic absorption spectrophotometry for mercury, lead, cadmium and arsenic. Age estimates were made by counting dentine layers in the canine teeth in fur seals. In fur seals total mercury was higher in liver than in muscle or kidney. Liver mercury ranged from 0.1-0.3 ppm in pups to 19-172 ppm in adult females. Lead and cadmium levels were generally higher in kidney than liver; arsenic was not detected in any of the samples. Only mercury in liver correlates with age, indicating accumulation with time. Harbor seals are nonmigratory; metal levels reflect the geographical concentrations of contaminants. Seals from San Miguel Island had significantly higher mercury levels (one seal had 700 ppm in the liver) than those from Pribilof Island. With the exception of this one animal, fur and harbor seals had comparable mercury levels.
CADMIUM; CHROMIUM; COPPER; LEAD; MERCURY; ARSENIC; SEAL

<3>
Anas, R.E., Mercury in Fur Seals., In: Mercury in the Western Environment. Buhler, D.R. ed. Proc. of a Workshop, Portland, OR, Continuing Education Publications, Corvalis, O.R., 91-96 (1971)., Pribilof Is; Commander Is, Bering Sea; Robben Is, Okhotsk Sea

Tissues samples from juvenile, 2- and 3- year-old male, and 5- to 19- year old female fur seals (CALLORHIOUS URSINUS) were stored frozen and subsequently analyzed for total mercury by flameless atomic absorption spectrometry (AAS). Some brain and liver samples from females were analyzed by neutron activation analysis (NAA). For comparison mean mercury levels found in liver were: pups, 0.20 ppm; young males, 10.8 ppm; and adult females, 67.8 ppm. Correlation between liver mercury concnetration and age was significant. Correlation between mercury levels in muscle and age was not significant. The mean value of mercury in 7 brain samples from adult females was 0.222 ppm (NAA).
MERCURY; FUR SEALS

<4>
Bachmann, R.W.; Odum, E.P., Uptake of 65 Zn and Primary Productivity of Marine Benthic Algae., Limnol. Oceanogr., 5(4): 349-355 (1960)., Massachusetts, Woods Hole

Algae were maintained in light and dark bottles suspended in running-sea water aquaria at 22 deg C. and were maintained either in the light or dark. Other bottles were suspended at different depths in a marine pond to achieve a gradient of light intensities. Samples were removed periodically



over a 3.0 hr period; some over a 6 to 13 hr period. Net productivity, respiration, and gross productivity were measured and zinc 65 uptake calculated. Only light exposed algae took up zinc; labelled algae gave up zinc when maintained in the dark. In experiments in which CHAETOMORPHA LINUM was subjected to a range of light conditions, zinc uptake and oxygen production are directly related (correlation coefficient = 0.9555). Concluding, zinc-65 may serve as a tool to measure primary productivity.
ZINC-65; PRODUCTIVITY; BENTHOS; ALGA

<5>
Barber, R.T.; Vijayakumar, A.; Cross, F.A., Mercury Concentrations in Recent and Ninety-Year-Olde Benthopelagic Fish., Science, 178(4061): 636-639 (1972)., U.S., South Atlantic Coast

Recent and 1833 preserved specimens of halosaur (ALDROVANDRIA MACROCHIR), a macrourid (CHALINURA), and a morid (ANTIMORA) were mercury analysed for mercury by two teams, one using a flameless atomic absorption analyzer and the other using an atomic absorption. Though the three groups of fish were taken from similar habitats with similar mercury pollution levels, the halosaur, in both recent and 1833 samples, had markedly lower mercury levels than the other groups. Also, in the halosuar, a size-concentration study showed a high correlation for both recent and preserved samples. The fact that mercury levels in halosuar, have remained essentially unchanged over a 90 year period in which the world mercury flux has increased indicates that water mercury levels may not be the most important factor determining the mercury concentration fish.
MERCURY; FISH

<6>
Beasley, T.M., Mercury in Selected Fish Protein Concentrates., Environ. Sci. Technol., 5(7): 634-635 (1971).

Colorimetric determinations of mercury content using dithizonate were made on fish protein concentrates (FPC). Significant levels of mercury were measured. Samples from fish taken from the open seas are suprisingly similar (0.34-0.60 ug/g dry weight) and correspond well with expected values; food chain concentration was considered also. All FPC measured exceed the "practical residue limit" set by the Food and Agricultural Organization of the U.N.; several exceeded the "action level" recommended by the USFDA.
FISH; MERCURY

<7>
Bender, M.E.; Huggett, R.J.; Slone, H.D., Heavy Metals -- an Inventory of Existing Conditions., J. Wash. Acad. Sci., 62(2):144-153(1972)., Chesapeake Bay

Samples of sediment, water, and marine animals were collected from the James, York, and Rappahannock Rivers in the Chesapeake Bay area. Samples were analyzed for several metals by flameless atomic absorption spectrophotometry. No difference existed between mercury levels in water from the three rivers. In specimens collected, the lowest levels of mercury were found in lobster from Norfolk Canyon whereas the highest levels were found in striped bass (0.13 ug/g), which is well below the 0.50 ug/g FDA Limit. Mercury levels in oyster (soft parts) were not correlated with age. The Elizabeth River and "Hampton Roads" are contributing to high zinc levels in oysters in their immediate areas and in the lower reaches of the James River. Sediment analysis enabled investigators to pinpoint time and source of heavy metal contamination.
MERCURY; ZINC; COPPER; OYSTER; FISH; LOBSTER

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Bertine, K.K.; Goldberg, E.D., Trace Elements in Clams, Mussels, and Shrimp., Limnol. Oceanogr., 17(6): 877-884 (1972).

Shell or tissue portions of fresh or museum specimens of clam, shrimp, or mussel from European coastal waters were dried and analyzed by neutron activation analysis. In clam (ENSIS SP. 1-4) metal composition of shells (ppm) ranged from 0.27 (1909) to 2.10 (1949) for zinc and from 0.012 (1949) to 0.42 (1909) for mercury. In mussel (MYTILUS SP. 1-3) levels of metals in shells (ppm) ranged from 0.28 (1915) to 1.99 (1897) for zinc; 0.03 (1968) to 2.28 (1870) for mercury. In 1971, MYTILUS had concentrations in fresh soft tissue (ppm) of 29 to 95 for zinc and 0.47 to 2.27 for mercury. Concentration factors in shrimp tissue were 3,900 for zinc and 43,000 for mercury.
SHRIMP; CLAM; MUSSEL; ZINC; MERCURY

<9>
Boney, A.D., Sub-Lethal Effects of Mercury on Marine Algae., Mar. Pollut. Bull., 2(5): 69-71 (1971).

Populations of 2-day-old sporelings of the red alga PLUMARIA ELEGANS were exposed to 0.12, 0.25, 0.5, or 1.0 ppm HgCl2 for 1 to 24 hr. and percent growth inhibition was measured 14 days later. Fifty per cent inhibition was observed for plants exposed at 1.0 ppm for 6 hr; at 0.5 ppm, 12 hr; 0.25 ppm, 24 hr; and 0.25 ppm, not reached in 12 hr. Plants were also exposed to n-C3H7-HgCl or n-C4H9-HgCl at levels of 0.05 and 0.25 ppm Hg for 2.5 to 90 min. Organomercurials were seen to be many times more toxic, at both lethal and sublethal levels, than inorganic mercury; n-C4H9-HgCl being more toxic than n-C3HF-HgCl.
MERCURY; ORGANOMERCURIALS; TOXICITY; ALGA

<10>
Braham, H.W., Lead in the California Sea Lion (ZALOPHUS CALIFORNIANUS)., Environ. Pollut., 5:253-258 (1973)., California; San Luis Obispo County (coast)

Subsamples from 19 organs and tissues from freshly killed sea lions were analysed by atomic absorption spectrophotometry: 204/242 samples contained detectable amounts of lead. Mean levels for each tissue ranged from 34.2 ppm (humerus) to 0.3 ppm (fat). Levels were generally higher in hard as opposed to soft tissue, and in females, versus males. Only brain tissue showed lead at toxic concentrations, though intestinal levels were also high. Because the sea lion is a coastal dweller and lead levels are comparable to those in humans, these data reflect relatively equal exposure to lead by coastal and terrestrial animals.
LEAD; SEA LION

<11>
Brereton, A.; Lord, H.; Thornton, I.; Webb, J.S., Effect of Zinc on Growth and Development of Larvae of the Pacific Oyster CRASSOSTREA GIGAS., Mar. Biol., 19: 96-101 (1973)., North Wales, Conway

Recently-fertilized eggs of Pacific oysters were maintained for three days at 29 ppth salinity, 20-22 deg C in sterilized, filtered seawater containing constant zinc levels of 12-13 (control), 125, 250, or 500 ug/l as zinc sulfate or metal-rich mine water. After two days, larvae were transferred to fresh treatment solutions every 24 hours, fed CHAETOCEROS CALCITRANS, ISOCHRYSIS GALBANA MONOCRYSUS LUTHERII, and CYCLOTELLA NANA and maintained at 26 deg C. for 5 days. Every 48 hours larva samples were examined for size, behavior, and structure. Mine water treatments resulted in higher mortality, except when compared to the 500 zinc ug/l level. Behavior, structural development, size, and growth rate are adversely affected in the presence of zinc, the effect being a function of concentration. Subsequent experiments showed that 100 and 150 ug zinc/l levels affect size and growth rates after 4 days, but 50 ug/l treated oysters did not differ from controls.
ZINC; GROWTH; LARVA; OYSTER; MORPHOGENESIS

<12>
Brooks, R.R.; Rumsby, M.G., The Biogeochemistry of Trace Element Uptake by Some New Zealand Bivalves., Limnol. Oceanogr., 10: 521-527 (1965)., New Zealand

Scallop, mussel, and oyster soft parts were analyzed spectrographically. Composites of organs and sediments were also analyzed. Enrichment factors ranged in scallop from cadmium at 2,260,000 to molybdenum at 90; in oyster from cadmium at 318,000 to molybdenum at 30; and in mussel from chromium at 320,000 to molybdenum at 60. Results indicate that contamination by and particulate ingestion of sodimentary materail are significant factors in metal ion uptake. Lead and molybedenum are distributed uniformly in these three species; these two metals have obscure biochemical roles. Cadmium and zinc were below detection limits in sediment but high levels within the bivalves, pointing to the possibility that here exists a major pathway for the removal of these metals from sea water.
BIOGEOCHEMISTRY; OYSTER; MUSSEL; SCALLOP; MANGANESE; LEAD; CHROMIUM; MOLYBDENUM; VANADIUM; COPPER; SILVER; CADMIUM; ZINC; NICKEL; IRON

<13>
Brooks, R.R.; Rumsby, M.G., Studies on the Uptake of Cadmium by the Oysterm OSTREA SINUATA (Lamarck)., Aust. J. Mar. Freshwater Res., 15: 53-61 (1967)., New Zealand, Tasman Bay

Specimens of oysters collected from Tasman Bay were 1) freshly killed, 2) maintained for 100 hr in filtered sea water (0.8 u milipore) at 15 degrees C, or 3) maintained for 100 hr in filtered sea water to which 50 ppm cadmium had been added. Little difference in cadmium or zinc levels existed between fresh-killed and filtered sea water groups; lead levels in fresh-killed oysters was much higher than in those in filtered sea water. In the 50 ppm cadmium group, levels of cadmium in gill, visceral mass, and heart are particularly high. Fractionation ratios (concentration in animal: amount in sea water) decrease steadily with increasing sea water concentrations; uptake ceased at 40 ppm in muscle and 140 ppm in heart. Cadmium is strongly bound in intact heart tissue (as shown by labeling and dialysis) but can be removed by dialysis of heart homogenates; 25% of the radioactivity is protein bound.
OYSTER; CADMIUM; ZINC; LEAD; UPTAKE; ACCUMULATION

<14>
Brown, B.; Ahsanullah, M., Effect of Heavy Metals on Mortality and Growth., Mar. Pollut. Bull., 2(12): 182-187 (1971).

Photolactic ARTEMIA larvae (48 hrs. old) were used for mortality and growth studies; 16-day-old adults, for mortality studies. Twelve hour OPHRYOTROCHA larvae were used for mortality and growth studies; 15-day adults, for mortality studies. In mortality experiments using adult animals, the length of time at 1.0 ppm (one of six heavy metals) to reach 50% mortality is used to express relative toxicity. The ranking in ARTEMIA is as follows: mercury, copper, cadmium, iron, zinc, and lead; for OPHRYOTYOCHA: mercury, copper, zinc, cadmium, iron, and lead. ARTEMIA larvae are more sensitive to the lethal effects of copper and zinc than adults. Growth inhibition was achieved at the following concentrations: ARTEMIA 10-1 ppm (zinc), 10-5 ppm (lead); OPHRYOTROCHA 0.1-0.05 (copper). In ARTEMIA copper at 1.0 ppm had no effect; in OPHRYOTROCHA 0.1 ppm zinc or 10 ppm lead had no effect.
LARVA; COPPER; ZINC; LEAD; IRON; MERCURY; CADMIUM; ARTEMIA; OPHRYOTROCHA

<15>
Bryan, G.W., The Occurrence and Seasonal Variation of Trace Metals in the Scallops PECTEN MAXIMUS(L.) and CHLAMYS OPERCULARIS(L.)., J. Mar. Biol. Assoc. U.K., 53: 145-166 (1973).

Commercial size scallops (PECTEN MAXIMUS and CHLAMYS OPERCULARIS) were collected from the Looe Grounds (10 miles W.S.W. of Plymouth, Great Britain). Animals were held overnight in sea water having low trace metal content before analysis. Atomic absorption spectrophotometric analysis of soft parts for zinc, manganese, copper, and iron over a two year period and lead, cobalt, and nickel over a one year period. Higher iron, cadmium, and aluminum levels were found in whole soft parts of PECTEN than CHLAMYS; in either species, digestive gland or kidney contained highest concentrations of metals. Seasonal variation in lead and zinc levels was found in both species. Absorption and excretion seasonal variation is thought mainly responsible for these cyclic changes.
SEASONAL VARIATION; SCALLOP; SILVER; COBALT; CHROMIUM; COPPER; MANGANESE; NICKEL; LEAD; ZINC

<16>
Bryan, G.W., The Effects of Heavy Metals (other than Mercury) on Marine and Estuarine Organisms., Proc. Roy. Soc. Lond. B., 177: 389-410 (1971).

This review of the literature details the effects of heavy metals, sans mercury, on marine and estuarine organisms. Sections discuss the fate of heavy metals in coastal regions; behavior of heavy metals in marine organisms (absorption from solution, absorption from ingested food or particles, excretion, and storage); and, detrimental effects of heavy metals, highlighting lethal, sublethal, inhibitory, and behavioral effects.
MAGNESIUM; MANGANESE; BARIUM; STRONTIUM; CALCIUM; ESTUARY; REVIEW; ZINC; COPPER; LEAD; CADMIUM; NICKEL; COBALT; SILVER; CHROMIUM; TOXICITY

<17>
Bryan, G.W., The Metabolism of Zn and 65 Zn in Crabs, Lobsters and Fresh-Water Crayfish., In "Radioecological Concentration Processes", Aberg, B. and Hungate, F.P., eds. Proc. Int. Symposium, Stockholm, Sweden, April 25-27, 1966, Pergamon Press, New York., 1005-1016 (1967).

Male intermoult crabs were 1) maintained in seawater containing carrier-free zinc-65, 2) fed labelled natural food, or 3) injected with a total of 1760 ug zinc over a 14 day period. Radioactivity in the crabs was monitored; copper and zinc levels of various tissues whole blood, urine, stomach fluid, muscle, hepatopancreas, gill, excretory organs, vas deferens, and shell were measured by the dithizone method. Potential equilibrium concentration factor for zinc-65 in crab is inversely proportional to the sea water zinc content. Zinc can be absorbed directly from sea water via the gills and rapidly and completely from food. Zinc is excreted via urine, feas, gill, and across the body surface; in lobster loss is via urine rather than the body surface.
ZINC-65; METABOLISM; CRAB; LOBSTER; CRAYFISH; ELIMINATION; CONCENTRATION FACTOR; ZINC

<18>
Bryan, G.W.; Hummerstone, L.G., Brown Seaweed as an Indicator of Heavy Metals in Estuaries in South-West England., J. Mar. Biol. Assoc. U.K., 53(3): 705-720 (1973)., England, Tamar Estuary

Samples of brown seaweed (FUCUS VESICULOSIS) collected over four different estuaries, along with accompanying water samples, were analyzed by atomic absorption spectrophotometry for copper, zinc, lead, manganese, and iron. Seawater washing was fairly effective in removing surface contamination, but cleaning with a brush removed slightly more. The older parts of the thallus

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contain higher metal levels than the tips and, for the most part, the stipe. Little seasonal variation was seen. Verticle distribution, i.e. where plants are located relative to tide (water depth), had little effect on zinc levels, but lead concentrations were always higher on the lower than upper shore. Results indicate that concentrations of metals accumulated by FUCUS probably reflect the concentrations dissolved in the water.
SEAWEED; ALGA; COPPER; ZINC; LEAD; MANGANESE; IRON; CONCENTRATION FACTOR

<19>
Bryan, G.W.; Hummerstone, L.G., Adaptation of the Polychaete, NEREIS DIVERSICOLOR to Estaurine Sediments Containing High Concentrations of Zinc and Cadmium., J. Mar. Biol. Assoc. U.K., 53: 839-857 (1973).

In South-West England, sediments and polychaete samples were taken from several estaurine stations which represented highly polluted and relatively unpolluted areas. Samples were analyzed for zinc and cadmium by atomic absorption spectrophotometry. Zinc levels in sediments ranged from 100-3000 ug/g; in worms from 130 to 350 ug/g dry weight. Cadmium levels ranged from 0.2-9.3 ug/g in sediment and from 0.08-36 ug/g in worms. Cadmium levels in worms reflected sediment levels whereas zinc levels are regulated in the worm and are maintained within certain limits depending on several environmental factors. Worms "adapted" to a heavily zinc polluted environment have a greater capacity to limit zinc accumulation than those from unpolluted environments.
CADMIUM; ZINC; POLYCHAETE; ESTUARY; SEDIMENT

<20>
Buhler, D.R.; Mate, B.R., Mercury Levels in California Sea Lions., In: Mercury in the Western Environment. Buhler, D.R. ed. Proc. of a Workshop, Portland, OR, Continuing Education Publications, Corvalis, O.R.., 97-101 (1971)., California

Attempting to correlate mercury levels and the severity of symptoms, selected tissues were removed from individuals sea lions from a population in which mercury poisoning had occurred. Total mercury and methylmercury analyses were performed. Tissue mean mercury levels were: liver, 137 ppm; kidney, 3.70 ppm; muscle, 1.41 ppm; cerebrum, 0.718 ppm; heart, 0.700 ppm; and cerebellum, 0.165 ppm. Only 2-3 per cent of the total liver mercury was methylmercury.
MERCURY; SEA LION; METHYLMERCURY

<21>
Button, D.K.; Dunker, S.S., Biological Effects of Copper and Arsenic Pollution., Report No. B71-8, 59 pp, Institute of Marine Science, University of Alaska College, NTIS PB-201 648 (1973)., Alaska

An isotope dilution bioassay technique was used to investigate nutrient incorporation kinetics. Copper exerts inhibitory effects on a marine microorganism, a yeast similar to RHODOTORULA RUBRA, only under manganese-dificient conditions. Presumably, arsenate and phosphate are transported and accumulated actively by the identical system because 1) arsentate inhibits phosphate transport; 2) phosphate inhibits arsenate transport, and 3) the uptake kinetics are similar. This system is nonsaturable. The inhibitory effect does not involve membrane diffusion limitation. Arsenate levels in environmental and potable water systems exceed the concentration sufficient to affect inhibition of phosphate transport, resulting in high death rates in these marine microorganisms.
MICROORGANISM; COPPER; MANGANESE; ARSENATE; PHOSPHATE; ACTIVE TRANSPORT; MEMBRANE KINETICS

<22>
Calabrese, A.; Collier, R.S.; Nelson, D.A.; MacInnes, J.R., The Toxicity of Heavy Metals to

<22>
<22> CONT.
Embryos of the American Oyster CRASSOSTREA VIRGINICA., Mar. Biol., 18: 162-166 (1973).

Adult oysters were induced to spawn in natural sea water in the laboratory and were transferred later to synthetic sea water while spawning was in progress. A known number of fertilized eggs was exposed to one of a range of concentrations of a metal salt for 42-48 hrs. Among the metal salts tested were: cadmium chloride, lead nitrate, mercuric chloride, sodium arsenite, and zinc chloride. Lethality (50 and 100%) of the metal salts occurred at the following concentrations (ppm): mercury 0.008, 0.0056; zinc 0.50, 0.31; cadmium --, 3.80; lead --, 2.45; and arsenic 12.0, 7.50.
OYSTER; EMBRYO; TOXICITY; ARSENIC; CADMIUM; COPPER; MAGNESIUM; ALUMINUM; ZINC; SILVER; MERCURY; NICKEL; CHROMIUM

<23>
Calabrese, A.; Nelson, D.A., Inhibition of Embryonic Development of the Hard Clam, MERCENARIA MERCENARIA, by Heavy Metals., Bull. Environ. Contam. Toxicol., 11(1): 92-97 (1974).

In the laboratory adult clams were induced to spawn in natural sea water and subsequently were transferred to synthetic sea water while spawning was in progress. A known number of fertilized eggs was exposed to one of ten concentrations of a metal salt for 42-48 hrs. Among the metal salts tested were: lead nitrate, mercuric chloride, and zinc chloride. Mortality (0, 50, and 100%) occurred at the following concentrations (ppm): mercuric chloride 0.0025, 0.0048, and 0.0075; zinc chloride 0.095, 0.166, and 0.25; lead nitrate 0.40, 0.78, and 1.20. Compared with oysters tested in a similar manner, clam embryos are 1) more sensitive to lead 2) somewhat more sensitive to zinc, and 3) as sensitive to mercury.
LEAD; MERCURY; ZINC; CLAM; EMBRYO

<24>
Chapman, A.C., On the Presence of Compounds of Arsenic in Marine Crustaceans and Shellfish., Analyst, 51:548-563 (1926)., England, Coast

Levels of arsenic in various marine crustacea and shellfish are reported (ppm wet wt.): oysters (a), 3-10; oysters (b) 33-70; escallops, 36-85; mussels, 36-119; cockles, 17-40; periwinkles, 20-40; lobsters, 18-40; prawns (a) 38-100; prawns (b), 36-174; shrimps 12-40; crab 36-70. Levels in seawater are reported to be 0.14-1.0 ppm. In flat fish arsenic occurred at 3-10 ppm. In shellfish and crustacea arsenic is believed to occur in a complex organic form of low toxicity.
ARSENIC; MARINE BIOTA; ARSENO ORGANIC COMPOUND; ANALYSIS

<25>
Childs, E.A.; Gaffke, J.N., Mercury Content of Oregon Groundfish., Fish. Bull., 71(3): 713-717 (1973)., Oregon, Coast

Samples of epaxial musculature from 16 species of groundfish collected off the Oregon Coast were analyzed using flameless atomic absorption spectroscopy. Only spiny dogfish, SQUALUS ACANTHIAS (0.6 ppm; 0.2-1.1 ppm) had mercury levels above the FDA guideline of 0.50 ppm. The mean mercury levels of all other species were significantly lower than 0.50 ppm, with the possible exceptions of lingcod, and canary rockfish. No correlation was seen between mercury content and sex, or length, or weight. No significant seasonal variation in content was observed in any species except sablefish in which 20 percent of the August, 1971, samples read above 0.05 ppm mercury.
MERCURY; FISH

<26>
Childs, E.A.; Gaffke, J.N.; Crawford, D.L., Exposure of Dogfish Shark Feti to Mercury., Bull. Environ. Contam. Toxicol., 9(5): 276-280 (1973), Oregon, Northern Coast

Homogenized SQUALLIS SUCKLEYI maternal and fetal samples were analyzed for mercury by flameless atomic absorption spectrophotometry. Fetal mercury levels (0.024 ppm, mean) were significantly lower than maternal levels (0.66 ppm) suggesting that mercury may be selectively excluded from the fetus. Fetal ash samples, however, were the same cr higher in mineral content other than mercury.
MERCURY; FETUS; SHARK; MATERNAL TRANSFER

<27>
Clarke, G.L., Poisoning and Recovery in Barnacles and Mussels., Biol. Bull., 92: 73-91 (1947).

Under laboratory conditions, adult barnacles (BALANUS BALANOIDES and BALANUM EBURNEUS) and mussels (MYTILUS EDULIS) were exposed to various metallic salts, including mercuric chloride and zinc sulfate, in natural sea water. The effect of mercuric chloride on the development of barnacle nauplii was also studied. Concentrations of metal salts (mg/l) necessary to kill barnacles in 2 and in 5 days are: B. BALANOIDES - mercuric chloride 1.0 and 0.5; zinc nitrate 32.0 and 8.0. A rating system was developed by which barnacles, and to a lesser extent mussels, could be evaluated as to the progress of "lethal poisoning." In barnacles, removal to fresh sea water at even the next to final stage (death) resulted in complete recovery in a few days. In mussels recovery did not occur after the late stages of poisoning had been reached. Mercuric chloride was inhibitory ot development of barnacle nauplii at low concentrations (16.6 mg Hg/l.) but levels high enough to prevent metamorphosis were above those lethal for adults.
BARNACLE; MUSSEL; ZINC; SILVER; MERCURY; COPPER; NAUPLII

<28>
Cocoros, G.; Cahn, P.H.; Siler, W., Mercury Concentration in Fish, Plankton and Water from Three Western Atlantic Estuaries., J. Fish Biol., 5(6): 641-647 (1973)., North Carolina, Core Sound; Maryland, Chesapeake Bay; New York, Oyster Bay

Samples of menhaden (20 in year class 1 and 2) and plankton were taken from three Atlantic estuaries, stored frozen, and subsequently analyzed for total mercury content by flameless atomic absorption spectrophotometry. Though the water in Chesapeake Bay showed the lowest mercury levels, fish and plankton caught in this estaury contained the highest levels. Chesapeake Bay plankton samples were primarily phytoplankton, while those from North Carolina, and New York were mainly zooplankton. Mercury concentrations were significantly different among the three areas for all three sample types. Concentration factors in Maryland phytoplankton were four times higher than N.C. or N.Y. zooplankton; concentration ratios from water-to-menhaden range from 308 to 1530. The plankton-to-menhaden concentration factor was a uniform 2.2 to 2.6 (2.4 mean). Estuarine water mercury levels are 3-10 times those reported for open sea.
MERCURY; FISH; PLANKTON; ESTUARY; MENHADEN

<29>
Collier, R.S.; Miller, J.E.; Dawson, M.A.; Thurberg, F.P., Physiological Response of Mud Crab, EURYPANOPEUS DEPRESSUS to Cadmium., Bull. Environ. Contam. Toxicol., 10(6): 378-382 (1973).

Crabs--maintained in a synthetic medium of 25 ppt salinity, pH 7.0, and 21 deg C--were exposed to cadmium levels ranging from 1.0 to 12.0 ppm. At the end of a 72 hr. exposure, oxygen consumption measures were made a) on whole animals exposed to

<29> CONT.
0.0, 3.0, 4.0, 6.0, and 7.0 ppm cadmium and b) on excised gill tissue from animals exposed to 0.0, 4.0, and 7.0 ppm. Lethal concentration values (LC0, LC50, and LC100) were 1.0, 4.9, and 11.0 ppm. Confidence limits for the (probit) LC50 were 3.9 to 5.4 ppm at the 95 percent level. Oxygen consumption rates of gill tissue decreased with higher cadmium levels.
CADMIUM; MARINE BIOTA; SHELLFISH; FISH; TEMPERATURE; SALINITY; TOXICITY; OXYGEN COMSUMPTION

<30>
Conner, E.D.S.; Sparrow, B.W., The modes of action of toxic agents. I. Observations on the posioning of certain crustaceans by copper and mercury., J. Mar. Biol. Assoc. U.K., 35:531-548 (1956)., England, Devon

Groups of 50-100 larvae -- ARTEMIA SALINA, ACARTIA CLAUSI, and ELMINIUM MODESTUS -- were exposed to various concentrations of meruric chloride, mercuric iodide, and ethylmercuric chloride. Results were compared as that concentration (mg Hg/l) required to produce 50 percent mortality in 2.5 hrs: ACARTIA 0.05; ELMINIUS 0.30,and ARTEMIA 800. When copper and mercury were tested together, as the levels of copper in the mixture increased over mercury levels the synergistic toxicity rose until a 20.1 concentration was reached. This synergism was less pronounced in ACARTIA than ARTEMIA. ARTEMIA pretreated by exposure to 1g/l Cu as copper sodium citrate for either 5 min or 1 hr were markedly less resistant to mercury toxicity. Conversely, mercury pretreatment potentiated copper toxicity in ARTEMIA. Potentiation effect of either metal were diminished by glutathione or cysteine treatment. Physiologically copper inhibits respiration in ARTHEMIA whereas mercury has a greater effect on motility.
TOXICITY; MERCURY; COPPER

<31>
Connor, P.M., Acute Toxicity of Heavy Metals to Some Marine Larvae., Mar. Pollut. Bull., 3(12): 190-192 (1972)., Norway

Oyster, shrimp, crab, and lobster larvae 1-3 days old were maintained in sea water at 15 degrees C for 64 hrs. Concentrations of copper, mercury, and zinc were tested for acute (64 hr) toxicity. The median effective times in hours (ET50) for mercury at 0.1 ppm or zinc at 1.0 ppm were: crab (CARCINUS MAENUS) 13.5, 47; shrimp (CRANGON CARNGON) 14.25, -- ; lobster (HOMARUS GAMMARUS) 22.5, --. Oyster (OSTREA EDULIS) ET50 for mercury at 0.0033 ppm was 4.2 hrs. In order of decreasing toxicity to mercury larvae rank oyster, shrimp or crab, and lobster. Ratios of median lethal concentrations (48 hr) for adults over larvae (A/L) are: mercury - crab 85.7, shrimp 570.0, oyster 4200-1272; zinc - crab 14.5.
LARVA; TOXICITY; MERCURY; ZINC; COPPER; LOBSTER; CRAB; SHRIMP; OYSTER

<32>
Corner, E.D.S., The Poisoning of MAIA SQINADO (Herbst) by Certain Compounds of Mercury., Biochem. Pharmacol., 2: 121-132 (1959).

Accumulation and toxic effects of mercury were studied in crabs exposed to sea water or injection containing either HgCl2 (Hg-203), 10mg Hg/l or n-C5H11HgCi (Hg-203) , 0.25 mg Hg/l. Observations included: amino-N in urine vs blood; rate of mercury uptake; distribution of mercury in crab; and sulfate excretion. Among the more significant results are: rate of uptake and distribution of mercury is marked different for HgCl2 and n-C5H10HgCl; loss of mercury was slower in the injected animals; urine: blood amino-nitrogen-ratios increased steadily during exposure to HgCl2 in sea water but did not increase after 7 hr with n-C5H11HgCl; the increased urine: blood ratio persists for more than 4 weeks

<29>
post-treatment regardless of compcund or exposure route; no influence on sulfate excretion was observed.
MERCURY; CRAB; PRAWN; TOXICITY

<33>
Cox, H.E., On Certain Methods for the Determination of Small Quantities of Arsenic, and Its Occurrence in Urine and in Fish., Analyst, 50: 3-13 (1924)., Sweden; England

Several preparative methods of wet tissue acid digestion for the determination of arsenic revealed that the nitric and sulfuric acid digestion of Ramberg is superior. Arsenic levels in marine fish species in British and Swedish waters as determined by this preferred method range from 0.01 to 0.30 mg/100g. Evidence exists for the presence of and increased excretion of arsenic in humans as a result of fish consumption.
ARSENIC; ANALYSIS; FISH; HUMAN

<34>
Cross, F.A.; Duke, T.W.; Willis, J.N., Biogeochemistry of Trace Elements in a Coastal Plain Estuary: Distribution of Manganese Iron, and Zinc in Sediments, Water, and Polychaetous Worms., Chesapeake Sci., 11(4): 221-234 (1970)., Chesapeake Bay

The Newport River Estuary was the site for a 2-year study of the elemental composition of biota, sediments, and water. Samples were taken from three stations having similar temperature and pH but ranging in salinity from 0.2 to 31.8 ppth (means). Sediment and water were sampled monthly; sediment samples were either are dominantly sandy or muddy. Polychaete worms were sampled bimonthly, washed and dried prior to chemical analysis; sediment samples were also taken at at these times. Levels of manganese, iron, and zinc in sediments varied with element, station, time, and sediment type. At each station iron levels in sediment and water were higher than manganese or zinc, zinc was the least abundant. Median concentration of manganese and iron decreased in a seaward direction whereas zinc levels remained relatively constant. Metal concentrations were higher in muddy versus sandy sediments. Occurrence of manganese and iron correlate. Polychaete worms (six species studied) concentrate these metals more so than sediment and water in the order zinc greater than iron greater than manganese.
ZINC; MANGANESE; IRON; POLYCHAETE WORM; SEDIMENT; ESTUARY

<35>
Cross, F.A.; Hardy, L.H.; Jones, N.Y.; Barber, R.T., Relation between Total Body Weight and Concentrations of Manganese, Iron, Copper, Zinc, and Mercury in White Muscle of Bluefish (POMATOMUS SALTATRIX) and a Bathyl-demersal Fish ANTIMORA ROSTRATA., J. Fish. Res. Board Can., 30(9):1287-1291(1973)., North Carolina, Morehead City, Cape Hatteras

Bluefish and morids caught during 1971-1972 were weighed, measured, filleted, and stored frozen for chemical analyses. Correlation between total body weight (TBW) and mercury is direct for both species; iron in morids; copper and zinc in bluefish. Inverse relationships exist in morids for copper and zinc; in bluefish for iron. Accumulation patterns in fish appear to vary as a function of species, size, and the metal.
BODY WEIGHT; MANGANESE; IRON; COPPER; ZINC; MERCURY; BLUEFISH; BATHYL-DEMERSAL FISH

<36>
Cross, F.A.; Willis, J.N.; Baptist, J.P., Distribution of Radioactive and Stable Zinc in an Experimental Marine Ecosystem., J. Fish. Res. Board Can., 28(11): 1783-1788 (1971).

<36>
<36> CONT.
CHLAMYDOMONA SP., CHLORELLA SP., DUNALIELLA SP., CARTERIA SP. and NITZSHCIA CLOSTERIUM with culture media were added to filtered sea water (30 ppth salinity). The system was lighted 12 hr/day and maintained at 20 deg. C. A natural population of SPIRULINA sp., LYNAGBYA sp., diatoms, as well as red and green algae established after 8 months. At this time, 1 mCi of zinc-65 (1.17 mCi/mg) in dilute HCl was added. Four months later, an algal bloom occurred. Analyses of particulate samples, sea water, and benthic algae taken subsequently revealed 1) sea water specific activity remained higher than that of particulate matter (CHLORELLA and NITZSCHIA), 2) sepcific activity of benthic algal was similar to sea water, and 3) concentration factors for particulates were 980 for zinc-65 and 1400 for stable zinc.
ZINC; PLANKTON; BENTHOS; CONCENTRATION FACTOR

<37>
Cunningham, P.A.; Tripp, M.R., Accumulation and Depuration of Mercury in the American Oyster CRASSOSTREA VIRGINICA., Mar. Biol., 20(1): 14-19 (1973)., Delaware

Adult oysters were exposed to either 10 or 100 ppb mercury, as mercuric acetate, for 12 hr. per day for 2 months. Subsequently aquaria were cleaned and oysters were observed and sampled for 6 months (only 32 days in the 100 ppb group due to mortality). Control oysters maintained a mean concentration of 350 ppb mercury throughout the experiment. Within 45 days in the accumulation period maximum tissue concentration was attained in both the 10 and 100 ppb groups: 27,950 and 140,710 ppb. After this time the mean concentration declined in both groups by 33 percent to 18,660 ppb and by 18 percent to 115,190, perhaps due to spawning. During the first 18 days of the depuration period the mercury level in the 10 ppb group declined 21 percent; in the 100 ppb, 43 percent. No futher decline was noted.
MERCURY; OYSTER; ELIMINATION; ACCUMULATION

<38>
Dondoroff, P.; Katz, M., Critical Review of Literature on the Toxicity of Industrial Wastes and their Components to Fish. II. The Metals, as Salts., Sew. Ind. Wastes, 25(7): 802-839 (1953).

This literature review examines 155 references published between 1881 and 1952, emphasizing those reports appearing after 1910 on the toxicity of heavy metals on both freshwater and marine fish. The subject headings include: Comparative Studies of the Metals; Antagonism and Synergism of Metal Cations; Hydrolysis and Precipitation of Metal Compounds; Mode of Action of Metal Salts and the Role of Anions; Miscellaneous Considerations--Temperature, Purity and Formula Weights of Chemicals Tested, and Volume of Experimental Solutions, and Acclimatization: and Toxicity of Metals Considered Individually (including Cadmium, Lead, Mercury and Zinc)
REVIEW; LEAD; ZINC; CADMIUM; MERCURY; TOXICITY; FISH; FRESHWATER

<39>
Duke, T.W.; Willis, J.N.; Price, T.J., Cycling of Trace Elements in the Estuarine Enviornment. I. Movement and Distribution of Zinc 65 and Stable Zinc in Experimental Ponds., Chesapeake Sci., 7(1): 1-10 (1966)., North Carolina, Rivers Island

Two experimental ponds, and an essentially open system (A) and the other a closed system, (B) both adjoining an estuary, had the following characteristics: pH (A) 7.4 to 9.0 and (B) 7.7 to 8.2; temperature, 23.8 to 32.4 and 17.0 to 29.0 deg C; salinity 22.0 to 36.1 and 24.9 to 34.8 ppth. Similar biotic populations were placed in either pond. Pond B however, had indigenous marsh grass and scallops while both had seaweed, snails, oysters, clams, croakers, and mummichogs. In pond A, fourteen hours after 10 mCi Zn 65 was added to pond A, 66% of had been absorbed and adsorbed onto biota, sediment, and other surfaces. After 10 days, 97% of the isotope had disappeared from the water. After 1 day in pond B, 82% of the zinc 65 was lost through tidal exchange. Distribution in sediments (99% at 100 days) and biota are similar for the two ponds; however, scallops (only in pond B) accumulated more zinc at a faster rate than all other species.
ZINC-65; CYCLING; SEAWEED; OYSTER; CLAM; SNAIL; CROAKER; MUMMICHOG; SCALLOP; MARSH GRASS; ZINC

<40>
Dutton, J.W.R.; Jefferies, D.F.; Folkard, A.R.; Jones, P.G.W., Trace Metals in the North Sea., Mar. Pollut. Bull., 4(8): 135-138 (1973).

Seawater, particulates, and biological samples taken from the North Sea during 1971 and analyzed for zinc, manganese, copper, nickel, and cadmium by atomic absorption spectrophotometry. Biolcgical materials were also analyzed for lead and silver. Mean seawater concentrations (ug/l) were: zinc 6.3 and cadmium 0.5. Soluble (s) and particulate (p) trace metal levels (ug/l) were surface-zinc(S) 0.8-12.0, (P) 3.9-16.3; cadmium (S) 0.1-1.6, (P) 0.1-0.3; bottom-zinc(S) 1.4-8.9, (P) 4.1-25.5; cadmium (S) 0.1-0.5, (P) 0.1-0.4. Mean levels ug/g dry wt for FUCUS VESICULOSUS were: zinc 85, cadmium 1.1, lead 4.5; for PORPHYRA UMBILICALIS zinc 56, cadmium 0.42, lead 2.8; and for PATELLA VULGATA zinc 120, cadmium 4.4, lead 3.7.
ZINC; LEAD; COPPER; CADMIUM; SILVER; MANGANESE; NICKEL; LIMPET; ALGA; SEAWEED

<41>
Eisler, R., Cadmium Poisoning in FUNDULUS HETEROCLITUS (Pisces: Cyprinodontidae) and other Marine Organisms., J. Fish. Res. Board Can., 28(9): 1225-1234 (1971)., Rhode Island

Several marine species were collected, maintained under laboratory conditions and exposed to various concentrations of cadmium as (Cd Cl2, for 96 h. The order of sensitivity as toxic level for 50 % of a population (TL50) in mg/L cadmium is: sandshrimp (0.32), hermit crab (0.32), grass shrimp (0. 42), common starfish (0. 82), common soft-shell clam (2.2), green crab (4.1), Atlantic oyster drill (6.6), eastern mud snail (21.0), blue mussel (25.0), sheepshead minnow (5.0), and mummichog (55.0). The mummichog tested at 5 or 20 deg C and 5, 15, 25, or 35 ppth salinity for toxicity at five cadmium levels showed the greatest sensitivity at 5 ppth salinity at both temperatures and greater sensitivity at 20 than 5 deg C. Further data are presented regarding posttreatment effects and pcstmortem accumulation and retention in the mummichog.
CADMIUM; FISH; TOXICITY; CRAB; MUMMICHOG; OYSTER; SNAIL; MUSSEL; STARFISH; SHRIMP

<42>
Eisler, R.; Gardner, G.R., Acute Toxicology to an Estuarine Teleost of Mixtures of Cadmium, Copper, and Zinc Salts., J. Fish Biol., 5:131-142 (1973)., Rhode Island; Jerusalem (US)

Mummichogs collected from a salt marsh and successfully acclimatized to a laboratory sea water system were exposed to one of a range of zinc/copper mixtures (mg/l): 60/0, 36/0, 12/1, 6/2, 3/3, 0/0, 0/1, and 0/8, or one of three cadmium concentrations (mg/l), 0, 1 and 10 for 96 hrs. The zinc/copper solutions that produced 30% mortality in the mummichog was selected for further study; the highest non-lethal cadmium level was 10 mg/l. Accumulation and distribution experiments were also accomplished. Zinc/copper combinations of 12/1, 6/2, and 3/3 caused 30% or greater mortality. The addition of 10 mg/l cadmium to all zinc/copper mixtures tested (except 0/0) produced increased mortality; 1 mg/l cadmium produced increased mortality for 3/3, 0/1, and 0/8 groups. Zinc

<42> CONT.
levels in fish exposed to 60 and 36 mg/l zinc or 12/1/0 zinc/copper/cadmium (mg/l) were above normal values. Presence of cadmium in the solution inhibited zinc uptake; cadmium levels in fish for all groups reflects proportionately the cadmium present in that respective test solution; copper levels were elevated in fish exposed to 8 mgl/l. The presence of copper did not effect zinc uptake; presence of zinc or cadmium did not effect copper uptake. Histopathology is detailed.
CADMIUM; COPPER; ZINC; TOXICITY; MUMMICHOG

<43>
Eisler, R.; LaRoche, G., Elemental Composition of the Estuarine Teleost FUNDULUS HETEROCLITUS (L.)., J. Exp. Mar. Biol. Ecol., 9: 29-42 (1972)., Rhode Island; Jerusalem

Mummichogs collected and held for 3-30 days were anlaysed by atomic absorption spectrophotometry for up to 23 elements. In laboratory experiments in which variables such as sex, length, temperature (5-20 deg C), and salinity (5-7 ppth) were tested with respect to elemental composition, only calcium, copper, iron, potassium, magnesium, manganese, sodium, strontium, and zinc levels were detectable; other elements were below sensitivity limits. Sex or temperature-salinity conditions were not correlated with elemental composition. Animals held for 30 days in sea water contained lesser amounts of total ash than those held for 3 days; there was an overall loss of all elements measured, particularly sodium and magnesium. If instead, fish are maintained in the synthetic medium MNWQL, elemental composition is less depleted.
MUMMICHOG; SODIUM; POTASSIUM; MAGNESIUM; CADMIUM; SILICON; ZINC; FISH

<44>
Elderfield, H.; Thornton, I.; Webb, J.S., Heavy Metals and Oyster Culture in Wales., Mar. Pollut. Bull., 2(3): 44-47 (1971)., North Wales; Conway

Lead and zinc pollution by the mining industry in the river catchment area is implicated in poor performance of oyster larvae in a hatchery adjoining the estuary. Adult breeding stock held in the hatchery for up to 14 weeks was periodically subjected to zinc-rich water containing particulate matter high in lead and zinc. Batches of larvae are released by the breeding oysters almost daily so that most larvae are exposed to peak zinc levels at some time in their development. Turbidity also contributes to poor performance of larvae.
AQUACULTURE; OYSTER; ESTUARY; MINING WASTE

<45>
Ferrell, R.E.; Carville, T.E.; Martinez, J.D., Trace Metals in Oyster Shells., Environ. Lett., 4(4):311-316 (1973)., Timbalier Bay; Chesapeake Bay; Louisiana (Euhlan Bay)

Restaurant oyster shells from freshly killed oysters from two coastal sites and shells from oysters specifically gathered for this study from a third site were analyzed by atomic absorption spectrophctometry for lead, cadmium, zinc, and mercury among other metals. All metals were concentrated in shells as compared to sea water samples by a factor greater than one thousand. Lead was concentrated to the highest degree; mercury, the least. No difference in trace metal levels was observed among the three sites, although large standard deviations were observed for the means of some elements, for example, cadmium. Results are higher than those reported earlier (1962) by other investigators.
OYSTER; LEAD; MERCURY; ZINC; CADMIUM; CHROMIUM; COPPER; SHELL

<46>
Fowler, S.W.; Small, L.F.; Dean, J.M., Distribution

<42>
of Ingested Zinc-65 in the Tissues of Some Marine Crustaceans., J. Fish. Res. Board Can., 27(6): 1051-1058 (1970)., Washington, Puget Sound; Oregon

Two euphausiid species (EUPHAUSIA PACIFICA and THYSANOESSA SPINIFERA), a prawn (PASIPHAEA PACIFICA), and two shrimps (PASIPHAEA STENOLEPIS and P. PLATYCEROS) were used to examine the distribution of ingested zinc-65. Shrimp were exposed to 75 uCi carrier-free zinc-56/liter of seawater fro 24 hr, washed, and fed to the euphausiids and prawn which were subsequently killed and parts analyzed for radioactive zinc or sectioned for autoradiographic analysis. Zinc-65 was found: on the surface of the euphausiids between the folds and fissures; primarily in muscle in the inter-myofibrillar spaces; and in the eye between the ommatidia. Little was associated with the hepatopanceas or gut. In the prawn zinc-65 was located along the internal layers of the exoskeleton. Localization in the eye and gut was similar to the emphausiid. Muscle-heptaopancreas interfaces showed heavy local concentrations of zinc 65.
ZINC; ZINC-65; CRUSTACEAN; PRAWN; EUPHAUSIID; SHRIMP

<47>
Frazier, J.M., Current Status of Knowledge of the Biological Effects of Heavy Metals in the Chesapeake Bay., Chesapeake Sci., 13(Suppl): S149-S153 (1972)., USA; Chesapeake Bay

The impact of heavy metal contamination of Chesapeake Bay is examined in the literature from the standpoints 1) productivity of desirable species and 2) contamination of commercially important marine products. A wide range of plant and animal species are discussed in terms of the effect of heavy metal pollutions on productivity, the availability of metals to organisms, and actual metal levels in organisms.
SWORDFISH; BIOAVAILABILITY; CATFISH; PRODUCTIVITY; MUSSEL; ALGA; FLOUNDER; KILLIFISH; CLAM; EEL; BASS; ESTUARY; TOXICITY; MERCURY; COPPER; ZINC; OYSTER; PERCH; CRAB; CADMIUM; IRON; MAGNESIUM; ARSENIC; LEAD

<48>
Freeman, H.C.; Horne, D.A., Total Mercury and Methylmercury Content of the American Eel (ANGUILLA ROSTRATA)., J. Fish. Res. Board Can., 30(3): 454-456 (1973)., Nova Scotia, Halifax

Two groups of eels were captured in the Medway River, Nova Scotia: one group was held in captivity in a cage in the river for 6 months before being killed and tissues analyzed for total mercury and methylmercury; the other was freshly caught. Homogenates of the dorsal muscle in each group were prepared for analysis. Total mercury was determined by flameless atomic absorption spectrometry; methylmercury by semimicro gas-liquid chromatography. No correlation was found between mercury levels and sex or weight. Of the 23 eels examined, 17 contained total mercury levels above the U.S.-Canadian allowable level of 0.5 ppm. Only two exceeded 1.0 ppm (both 1.3 ppm). The mean methylmercury level was 0.40 ppm, approximately 50% of the total mercury. Methylmercury levels differed little between the captive (45%) and the fresh caught (52%) groups.
MERCURY; METHYLMERCURY; EEL

<49>
Freeman, H.C.; Horne, D.A., Mercury in Canadian Seals., Bull. Environ. Contam. Toxicol., 10(3): 172-180 (1973)., Canada

Seal tissue samples from Eastern Canada were analyzed for mercury by flameless atomic absorption spectrophotometry. Claw sections from PHOCA HISPIDA (ringed) and ERIGNATHUS BARBATUS (bearded) seals had 3.7 to 0.47 ppm total average mercury; in general, mercury levels in the claw sections were not helpful in pinpointing high exposure periods. In HALICHOERUS GRYPUS mercury contamination

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<49> CONT.
increased with size and age; mercury levels were high in the fur, claws, liver, and kidneys of adults which appeared healthy. Mercury levels in maternal and fetal tissues indicate mercury is carried across the placental barrier, but is not concentrated in the fetus; in fact mercury was below maternal levels. Methylmercury levels were lower in feti than pregnant cows, lower with age, and lower in kidney and liver than other tissues.
MERCURY; SEAL; FETUS; METHYLMERCURY

<50>
Freeman, H.C.; Horne, D.A.; McTague, B.; McMenemy, M., Mercury in Some Canadian Atlantic Coast Fish and Shellfish., J. Fish. Res. Board Can., 31(3): 369-372 (1974)., Canada; Atlantic Coast

Following capture, duplicate acid digests of tissues were analyzed for mercury by flameless atomic spectrometry absorption. Clams, oysters, quahogs, mussels, Atlantic salmon, herring, halibut, haddock, hake, cusk, pollock, catfish, lumpfish, menhaden, squid, rock crab, redfish, cod, gaspereau, American plaice, winter flounder, shad, sea raven, throny skate, mackerel, red crab, silver hake, and deep sea lobster were caught and tissues samples for mercury analysis. No relationships were found between mercury levels and sex or weight of any species. Except for two groups of offshore lobsters (0.73 and 0.61 ppm mercury) all species contained less than 0.5 ppm mercury.
FISH; SHELLFISH; MERCURY

<51>
Gardner, G.R.; Yevich, P.P., Histological and Hematological Responses of an Estuarine Teleost to Cadmium., J. Fish. Res. Board Can., 27(12): 2185-2196 (1970)., Rhode Island

Groups of adult killifish, FUNDULUS HETEROCLITUS, were exposed for 1/2 to 48 hours under laboratory conditions to seawater containing 50 ppm cadmium. Microscopic examination of tissues from these fish revealed early pathologic response in the intestine (at 1 hr), followed by kidney and gill filament deterioration at 12 and 20 hr. Hematologic response was characterized by a steady increase in eosinophilic cells after an 8 hr. exposure, an increase and stabilization in numbers of eosinophilic granulocytes at 4 hr, cellular aberrances in granulocytes after 20 hr, and scalloped appearance of thrombocyte nuclei after 8 hr. Microhematocrits did not differ substantially from controls after 24 or 48 hr. Head kidney imprints showed a decrease in relative numbers of mature eosinophilic granulocytes after 8 hr.
CADMIUM; TOXICITY; FISH; KILLIFISH; HISTOLOGY; HEMATOLOGY

<52>
Gaskin, D.E.; Frank, R.; Holdrinet, M.; Ishida, K.; Walton, C.J.; Smith, M., Mercury, DDT, and PCB in Harbour Seals (PHOCA VITULINA) from the Bay of Fundy and Gulf of Maine., J. Fish. Res. Board Can., 30(3): 471-475 (1973).

Harbour seals were collected from three locations in the Bay or the Gulf and were analyzed by atomic absorption spectrophotometry. Total liver mercury was greater in adults from the Bay of Funday than in those from coastal areas. Percentage of methylmercury was lowest in the two specimens with highest total mercury levels (0.30 ppm of 13.10 ppm and 0.93 of 50.90).
MERCURY; SEAL; METHYLMERCURY

<53>
Gaskin, D.E.; Ishida, K.; Frank, R., Mercury in Harbour Porpoises (PHOCOENA PHOCOENA) from the Bay of Fundy Region., J. Fish. Res. Board Can., 29(11): 1644-1646 (1972).

Liver and muscle sections were taken from male and female harbour porpoises. Samples were stored frozen and mercury determined by atomic absorption spectrophotometry. Mercury levels were: muscle (male) 0.21-1.92 ppm, av 0.75 ppm, (female) 0.26-2.58 ppm, av. 1.02 ppm; liver (male) 0.89-18.30, (female) 0.55-91.30 ppm. A few estimations of the level of methylmercury showed that in muscle 84-100% of mercury was in this form; in liver, only 7.4-41%. Levels of methylmercury were greater in liver samples with higher total mercury levels; the higher the total mercury, level however the lower the porportion of the methylated form.
PORPOISE; MERCURY; SEX

<54>
Gray, J.S.; Ventilla, R.J., Growth Rates of Sediment-Living Marine Protozoan as a Toxicity Indicator for Heavy Metals., Ambio, 2(4): 118-121 (1973)., England, Robin Hood's Bay.

A ciliate protozoa, CRISTIGERA, was extracted from a sand sample and maintained on a pseudomonad diet. Temperate-salinity conditions which had proved to maximize growth rate were used. The effects of various concentrations of mercuric chloride, lead nitrate, and zinc sulfate were assessed as a reduction in the percentage growth rate constant, K. As little as 0.0025 ppm of mercuric chloride reduced K by 9.5 per cent; the highest level tested (0.005 ppm), by 12 per cent. Lead nitrate (0.3 ppm) reduced K by 11.7 per cent; zinc sulfate (0.25 ppm), by 13.7 percent. The inhibitory effect of the metal salts at the highest levels was nearly twice what would be expected if effects were merely additive. Zinc and lead levels found to inhibit growth in CRISTIGERA are the lowest recorded for marine organisms. Mercury levels are equivalent to that found in oyster and crab larvae. The hypersensitivity of CRISTIGERA to metals suggests a useful test organism indicator for heavy metals.
PROTOZOA; TOXICITY; SEDIMENT; MERCURY; LEAD; ZINC

<55>
Gutknecht, J., Zn-65 Uptake by Benthic Marine Algae., Limnol. Oceanogr., 8: 31-38 (1963).

Four seaweed species (FUCUS VESICULOSUS; ULVA LATICA; PORPHYRA UMBILICALIS; LAMINARIA AGARDI) were maintained in filtered sea water-at 23 deg C with a pH of 8.0 to which zinc-65 had been added. Plants were subsequently exposed to only dark or light, pH 7.3 or 8.6, and to the inhibitors phenylurethane or uranyl nitrate. Loss of zinc-65 was examined by removal of plants to non-radioactive environments. Light, pH, and temperature effects on loss rate were observed. Uptake of zinc-65 was promoted by light and high pH; plants in either inhibitor solution and dark took up less zinc 65-by about 10-15% in a 36 hr. period than those in inhibitor-light environments. Fresh weight concentration factors are: FUCUS 6,900; ULVA 4,100; POPHYRA 1,200. Loss of zinc-65 was faster with decreasing pH, with higher temperatures, and in the light. Loss was also more rapid when media zinc concentrations were higher. Other experiments involved zinc exchange in living and dead tissue, radioactivity of old versus young tissue, and internal pH changes in the light.
ZINC; UPTAKE; ALGA; BENTHOS; CONCENTRATION FACTOR; BIOLOGICAL HALF-TIME

<56>
Hannan, P.J.; Patouillet, C., Effect of Mercury on Algal Growth Rates., Biotechnol. Bioeng., 14: 93-101 (1972).

CHLORELLA PYRENOIDOSA, a freshwater alga, and 3 marine species, PHAEODACTYLUM TRICORNUIUM, CHAETOCEROS GALVESTONENSIS, and CYCLOTELLA NANA were treated in culture medium with 0.1 or 1.0 ppm copper, lead, or mercury. At 1.0 ppm both lead and copper showed no inhibitory effects, while mercury was 100 percent inhibitory in PHAEODACTYLUM; at 0.1 ppm mercury was also inhibitory. When 0.1 ppm of

<56> CONT.
mercury; silver, or cadmium was added to marine cultures in medium. Mercury was totally inhibitory, cadmium was nontoxic, and the toxicity of silver ranged from extreme (CHAETOCEROS and CYCLOTELLA) to none (PHAEDACTYLUM). Dimethylmercury (0.1 ppm Hg) is less toxic to these marine species than HgCl2; the most sensitive of these to the organic form is CHAETOCEROS.
MERCURY; TOXICITY; GROWTH; ALGA

<57>
Havre, G.N.; Underdal, B.; Christiansen, C., Cadmium Concentrations in Some Fish Species from a Coastal Area in Southern Norway., Oikos, 24(1): 155-157 (1973)., Norway

Fish muscle smples were wet ashed using sulfuric and nitric acids and boiling hydrogen peroxide. The cadmium ammonium pyrrolidine dithiocarbamate chelate was then analyzed by atomic absorption spectrophotometry to determine cadmium content. The following levels of cadmium were found (micrograms/g wet weight): cod, 0.003 to 0.012; whiting, C.002 to 0.029; herring, 0.004 to 0.033. Higher cadmium levels in herring could relate to 1) a higher percent of body weight made up of fat, or, 2) possible selective accumulation of cadmium. A correlation between cadmium concentration and total weight of fish was not established.
CADMIUM; FISH; COD; HERRING; ANALYSIS

<58>
Holden, A.V., Mercury in Fish and Shellfish. A Review., J. Food Technol., 8:1-25(1973).

An in-depth discussion is presented on the problem of a mercury-polluted hydrosphere leading consequently to contaminated fish and shellfish. The literature reviewed (83 references) details 1) the historical development of the mercury problem, 2) methodology of monitoring total mercury and methylmercury, 3) results of monitoring studies in fresh- and sea water fish, 4) effects of mercury on fish; and 5) acceptable limits of mercury in fish.
MERCURY; REVIEW; FISH; SHELLFISH

<59>
Huggett, R.J.; Bender, M.E.; Slone, H.D., Utilizing Metal Concentration Relationships in the Eastern Oyster (CRASSOSTREA VIRGINICA) to Detect Heavy Metal Pollution., Water Res., 7: 451-460 (1973)., Chesapeake Bay

Oysters (sample size of 495) were collected from coastal and estaurine beds in the Chesapeake Bay region. Salinity ranged from 7-32 ppth among stations. Five specimens from each site were shucked, digested, and analyzed for cadmium, copper, and zinc by atomic absorption spectrophotometry. Wide variation in the levels of copper, cadmium and zinc exists among individual oysters from the same site. No correlation was established between age (weight) and metal concentrations. Using mean values, a concentration gradient exists in the various river systems and from fresh water (high metal levels) to saltwater. A linear relationship between copper-zinc and zinc-cadmium levels exists in uncontaminated oysters.
ZINC; CADMIUM; OYSTER

<60>
Hussain, M.; Bleiler, E.L., Mercury in Australian oysters, Mar. Pollut. Bull., 4(3):44(1973)., Australia, Botany Bay and Georges River

Tissues from specimens of Sydney rock oyster (CRASSOSTREA COMMERCIALIS) were analyzed for mercury by atomic absorption spectrophotometry. Only trace amounts were found in either non-industrial (0.003 to 0.017 ppm) or industrial areas (0.006 to 0.017 ppm) indicating no mercury pollution in these areas.

<56>
MERCURY; OYSTER

<61>
Ireland, M.P., Result of Fluvial Zinc Pollution on the Zinc Content of Littoral and Sub-Littoral Organisms in Cardigan Bay, Wales., Environ. Pollut., 4: 27-35 (1973)., Wales, Cardigan Bay

Water samples from seven stations taken at 15 cm below the surface were filtered and concentrated; littoral and sublittoral animal species held overnight were analyzed by atomic absorption spectrophotometry. The highest zinc levels in sea water were found at Harbour Point (88 ug/l). Zinc concentrations in littoral species LITTORINA LITTOREA, MYTILUS EDULIS, and ACTINIA EQUINA were not significantly different; THAIS LAPILLUS and BALANUS BALANOIDES contained levels significantly higher than these with B. BALANOIDES being significantly higher than T. LAPILLUS. Zinc levels in all species were significantly higher at Alltwen than at Harbour Point or Morfa Bychan.
ZINC; MUSSEL; WHELK; PERIWINKLE; BARNACLE

<62>
Jaakkola, T.; Takahashi, H.; Miettinen, J.K., Cadmium Content in Sea Water, Bottom Sediment, Fish, Lichen, and Elk in Finland., In Environmental Quality and Safety. Global Aspects of Chemistry, Toxicology and Technology as Applied to the Environment. Coulston, F.; Korte, F., eds. Georg Thieme Publ., Stuttgart. Academic Press Inc., NY., 230-237 (1973)., Finland, Coast

Seawater was sampled, concentrated, and analysed for cadmium by atomic absorption spectrophotometry, average yield was 92 %. Results from the 12 locations ranged from 0.1 to 10.2 ppb; high levels were attributed to pollution by a zinc smelting operation in the vicinity. Cadmium levels in fish flesh were estimated by adding cadmium 109 to samples at the beginning of wet ashing and calculating dilution of the cadmium 109 by stable zinc. Liver contains about 10 times more cadmium than muscle from the same fish; kidney, 30 to 80 times. Levels in older fish were approximately 2 to 3 times those in younger fish. Fish taken from near the smelter contained roughly twice as much cadmium as other fish sampled.
CADMIUM; FISH; SMELTER; POLLUTION; SEA WATER

<63>
Jaakkola, T.; Takahashi, H.; Soininen, R.; Rissanen, K.; Miettinen, J.K., Cadmium Content of Sea Water, Bottom Sediment and Fish, and its Elimination Rate in Fish, In: Radiotracer Studies of Chemical Residues in Food and Agriculture, Proc. Joint FAO/IAEA Division of Atomic Energy in Food and Agriculture. Oct. 28-29, 1971. IAEA, Vienna, 69-75 (1972)., Finland, Gulf of Finland

Tissues from pike, ESOX LUCIUS L., relatively unpolluted areas in the Gulf of Finland were analyzed for cadmium by atomic absorption spectrophotometry. Muscle had the lowest cadmium levels, 2-3 ppb fresh weight; liver, about 10 times this amount; kidney, about 50 times. Four-hornet sculpin (MYOXOCOTTUS QUADRECORNIS) taken outside a mineral plant in Pori, contained 77 ppb cadmium fresh weight in muscle.
CADMIUM; SEA WATER; SEDIMENT; FISH

<64>
Jackim, E., Influence of Lead and other Metals on Fish Delta-aminolevulinate Dehydrase Activity., J. Fish. Res. Board Can., 30(4):560-562(1973).

Because lead inhibits delta-aminolevulinic acid dehydrase (ALA-D) activity in human and animal tissues, experiments were carried out using mummichog (FUNDULUS HETEROCLITUS) and winter flounder (PSEUDOPLEURONECTES AMERICANUS) to determine whether ALA-D activity could be used as a bioassay for lead in fish. Specificity of the lead

<64>
<64> CONT.
- ALA-D interaction was tested by exposing the fish to sublethal concentrations of various toxic metal salts and subsequently measuring ALA-D activity. Lead produces the most marked decrease in ALA-D activity followed by mercury and copper. Cadmium, zinc, and silver increased ALA-D activity.
LEAD; TOXICITY; ENZYME ACTIVITY; MERCURY; COPPER; CADMIUM; ZINC; FISH

<65>
Jarvenpaa, T.; Tillander, M.; Miettinen, J.K., Methylmercury: Half-time of Elimination in Flounder, Pike and Eel., Suomen Kemistilehti, B43: 439-441 (1970).

Flounder, pike, and eel maintained in seawater 6 ppth salinity, 2-11 degrees C were exposed to mercury-203 in the ionic or protein-bound form by peroral administration, or in the ionic form by intramuscular injection. Half-times were not significantly different for mercury forms or administration routes. Elimination rates were determined by whole-body counting of live fish for 100 days in a gamma spectrometer: flounder 700-780 days; pike 640-780 days; and eel 910-1030 days.
HALF-TIME; METHYLMERCURY; FLOUNDER; PIKE; EEL; ELIMINATION

<66>
Jinks, S.M.; Eisenbud, M., Concentration Factors in the Aquatic Environment., Radiat. Data Rep., 13(5): 243-247 (1972).

Concentration factors, defined as concentration of a substance in an organism divided by the concentration of the substance in ambient water, for fresh- and marine plant and animal groups are compiled from the literature. A brief discussion centers on variability of results as well as how and where errors are likely to occur. Zinc is among the metals considered.
CONCENTRATION FACTOR; REVIEW; FRESHWATER; ZINC

<67>
Jones, A.M.; Jones, Y.; Stewart, W.D.P., Mercury in Marine Organisms of the Tay Region., Nature, 238: 164-165 (1972)., England, Broughty Ferry and Arbroath

Several species of algae and molluscs were collected from two stations in the Tay region: one receiving a large freshwater discharge whereas the other is strictly marine. Samples were analyzed for mercury content using flamelss atomic absorption spectrophotometry. Algae from the "freshwater" station had high levels of mercury; from the "marine" station no detectable mercury was found. All three species of molluscs, each representing a link in the food chain, had high levels of mercury. Localization of mercury accumulation occurred in the stipe and holdfast of FUCUS; in the ctendia in MYTILUS EDULIS. Accumulation and loss rates were rapid in M. EDULIs ULVALATICA, AND PORPHYRA UMBILICALIS; the maximum concentration in the mollusc lagging 4 days behind the algae.
MERCURY; ALGA; LAMELLIBRANCH; GASTROPOD; MOLLUSC

<68>
Kauranen, P.; Jarvenpaa, T., Biological Half-Times of 210 Po and 210 Pb in some Marine Organisms., In: Radioactive Food Chains in the Subarctic Environment., U.S. Atomic Energy Commission Document No. C00-3011-1, paper 47, 11 pp (1973).

In the tissues of marine organisms polonium-210/lead-210 ratios have been reported to be greater than unity. Polonium therefore must have either a higher uptake efficiency somewhere in the food chain or a biological half-time greater than lead. Fifty percent of lead-212 introduced into a sea water aquarium housing the mussel, MYTILUS EDULTS was removed through adsorption, absorption, or ingestion in 30 min. In HARMOTHOE SARSI, 50 percent was removed in 4h, mostly through adsorption. Half-times were calculated for polonium-210 and lead-210 in the mussel, GAMMARUS (a fish) and on the polychete, HARMOTHOE. Differential absorption of polonium probably occurs at lower tropic levels. Longer biological half-times of polonium are not likely responsible for PO-210/Pb210 ratios of greater than 1 in many marine organisms.
LEAD-210; BIOLOGICAL HALF-TIME; MARINE BIOTA; POLONIUM; MUSSEL; FISH; POLYCHAETE

<69>
Keckes, S.; Miettinen, J.K., Mercury as a Marine Pollutant., In: Marine Pollution and Sea Life, Ruivo, M., (ed.), Fishing News Ltd., London., 276-289 (1970).

Literature from 327 references relating tc mercury pollution in the marine environment is discussed under the major headings: biogeochemistry (chemical properties, occurrence and distribution, circulation and transformation, acculation by fish, and transfer route), artificial sources (amounts produced or lost, uses, and control), and biological effects (toxicity, sensitivity, environment synergistic effects, and teratcgenesis.
REVIEW; MERCURY; TOXICITY

<70>
Kim, K.C.; Chu, R.C.; Barron, G.P., Mercury in Tissues and Lice of Northern Fur Seals., Bull. Environ. Contam. Toxicol., 11(3): 281-284 (1974)., Alaska; St. Paul Is.

Samples from two nursing cows (hair, blood, and milk), two new-born and three two-month-old pups (sucking lice, blood, and hair) were analyzed for mercury by flameless atomic absorption spectrophotometry. Hair contained the highest levels of mercury compared to other samples. Mercury levels were higher in cows and two-month-old pups than in newborns. Mercury is readily transferred from blood to milk and from maternal blood to feti in the fur seal. The good correlation between blood and lice suggests further examination. Hair mercury levels indicates that hair levels are a reliable, non-destructive index of mercury contamination in the fur seal.
MERCURY; FUR SEALS

<71>
Klein, D.H.; Goldberg, E.D., Mercury in the Marine Environment., Environ. Sci. Technol., 4(9): 465-467 (1970)., California, La Jolla and Palos Verdes, Coast.

Tissues were collected from 81 coastal marine organisms, mostly epibenthic fauna from inshore Pacific waters. Mercury levels varied within as well as among species. Cowry (Palos Veredes) had the highest mercury content, 21 ppm, whereas sea cucumber (La Jolla) had the lowest, 0.4 ppm. Though sediment and water samples near a sewage outfall showed very high mercury levels, organism levels taken near this site were comparable to those far removed. Concentration factors in the organisms sampled were five hundred times or more.
MERCURY; MARINE BIOTA

<72>
Knauer, G.A.; Martin, J.H., Mercury in a Marine Pelagic Food Chain., Limnol. Oceanogr., 17(6): 868-876 (1972)., California, Monterey Bay; Pacific Ocean, Monterey-Hawaii transect

In order to measure mercury in a lower trophic food chain, samples of plankton and anchovies were collected from both inshore and offshore locations. Samples were analyzed using flameless atomic absorption spectrophotometry. On a wet weight basis, phyto-and zooplankton average levels of mercury were identical; but, mercury levels on a

<72> CONT.
dry weight basis were twice as high in phytoplankton. No seasonal trends in mercury levels were seen in any group. Anchovie mercury levels showed wide variation, but on a dry weight basis were not significantly higher than the plankton levels. Organic mercury was 0-67 per cent of total mercury in phytoplankton; 76-100 per cent in anchovies. These data show no tendency for mercury accumulation in this marine food chain.
MERCURY; PLANKTON; ANCHOVY; FOOD CHAIN

<73>
Knauer, G.A.; Martin, J.H., Seasonal Variations of Cadmium Copper, Manganese, Lead, and Zinc in Water and Phytoplankton in Monterey Bay, California., Limncl. Oceanogr., 18(4):597-604(1973)., California, Monterey Bay

For one year nearshore samples of water and phytoplankton were collected and analyzed for cadmium, copper, manganese, lead, and zinc. Water samples were also taken on a California-Hawaii transect. Hydrographic periods - intense upswelling, low upswelling, oceanic, and mixed - have a greater effect on elemental composition of sea water than do biologic cycles. Cadmium, however, does decrease in seawater during periods of peak productivity. During periods of strong upswelling inshore levels of zinc are higher than offshore; cadmium and lead levels are usually about an order of magnitude higher inshore.
COPPER; CADMIUM; LEAD; ZINC; PHYTOPLANKTON; MANGANESE; SEASONAL VARIATION

<74>
Koeman, J.H.; Peeters, W.H.M.; Koudstaal-Hol, C.H.M.; Tjioe, P.S. DeGoeij, J.J.M., Mercury-Selenium Correlations in Marine Mammals., Nature, 245(5425): 385-386 (1973).

Neutron activation analysis of liver tissue from five seals revelaed selenium at 46 to 134 ppm, mercury at 257 to 326 ppm, cadmium at 0.05 tc 0.30 ppm, arsenic at 0.20 to 1.7 ppm, and zinc at 25 to 34 ppm. Mercury and selenium liver concentrations in marine mammals (seal, porpoise, and dolphin) strongly suggest a definite correlation--coefficient of 0.932 with no species differences. The average uptake of the two metals in the adult as calcualted by regression analysis to be 1:1 on a molecular basis. Neutron activation analysis of subcellular fractions of seal liver revealed 50 per cent of the mercury and selenium to be associated with the nuclei and cell wall material, again on a 1:1 basis. Mercury levels did not corelate well with the other elements.
MERCURY; SELENIUM; MAMMALS; CADMIUM; ARSENIC; ZINC; CELL FRACTIONATION

<75>
Kopfler, F.C., The Accumulation of Organic and Inorganic Mercury Compounds by the Eastern Oyster (CRASSOSTREA VIRGINICA)., Bull. Environ. Contam. Toxicol., 11(3): 275-280 (1974)., Alabama, Mobile Bay

Commercial size oysters were collected, acclimatized to laboratory conditions, exposed to either 50 ug/l mercury (organic or inorganic) at 0-10 deg C or 1 ug at 25-35 deg C. Measures were taken to insure no further mercury contamination reached the animals via the flowing seawater for the duration of the experiments. At intervals, oysters were removed and meats taken, homogenized, and analyzed by flameless atomic absorption spectrophotometry. At the 50 ug/l level, high mortality in the animals exposed to organic mercury and very rapid accumulation in all animals limited the amount of useful data gained. Average accumulation after one week was more than 1000 times the control values. Animals exposed to mercuric chloride had very high gill mercury levels. At the 1 ug level, inorganic mercury accumulated at a rate 4 times greater than organic.

<72>
Other metals were determined--cadmium, lead, and zinc--to ascertain exposure to mercury affected levels of these in oysters. Zinc levels decreased after exposure to mercury for one week; organomercury cause a 19 day decline; whereas mercuric chloride caused an increase during the third week.
MERCURY; OYSTER; BIOACCUMULATION

<76>
Kopfler, F.C.; Mayer, J., Concentrations of Five Trace Metals in the Waters and Oysters (CRASSOSTREA VIRGINICA) of Mobile Bay, Alabama., Proc. Nat. Shellfish. Assoc., 63: 27-34 (1973).

Oysters were collected, shucked and soft parts analyzed by atomic absorption spectrophotometry for cadmium, chromium, lead, and zinc. Median metal concentrations in oysters (mg/kg) and water samples (ug/kg) from Mobile Bay were: cadmium 0.45-1.00 and 0.3-0.6; lead 0.67-0.88 and 0.5-3.0; and zinc 319-1980 and 2.2-3.6. Compared to Atlantic Coast oysters, those in Mobile Bay were lower in cadmium and zinc and about twice as high in lead.
OYSTER; CADMIUM; CHROMIUM; LEAD; ZINC

<77>
Laumond, F.; Neuburger, M.; Donnier, B.; Fourcy, A.; Bittel, R.; Aubert, M., Experimental Investigations, at Laboratory, on the Transfer of Mercury in Marine Trophic Chains., Rev. Int. Oceanogr. Med., 31-32; 47-53 (1973).

Transfer of mercury was studied in two marine food chains: sea water-plankton (ASTERIONELLA JAPONICA, DIOGENES SP., and ARTEMIA SALINA)- fish (CUPRINIDAE) and sea water-phytoplankton (DIOGENES SP.)- molluscs. Multiple pollutants including mercury were added to sea water aquaria containing plankton and fish or mussels. Contamination schedule for the pelagic (fish) chain was: plankton 15 days; fish 38 or 71 days; plantkon 8 days; and mussel 8 days. Mercury determinations were made by extraction titration with dithizone or neutron activation analysis. Addition of 0.015 ppm of mercury to sea water (pelagic chain) results in concentration factors of 1) 20 to 100 for plankton and 20 to 40 for fish; 2) 0.1 ppm in neritic chain, 1000 plus for phytoplankton, and 200-400 for mussels. The presence of other pollutants (all organic) did not effect the accumulation of mercury significantly.
MERCURY; TRANSFER; FOOD CHAIN; ALGA; FISH; MUSSEL

<78>
Leatherland, T.M.; Burton, J.D.; Culkin, F.; McCartney, M.J.; Morris, R.J., Concentration of Some Trace Metals in Pelagic Organisms and of Mercury in Northeast Atlantic Ocean Water, Deep-Sea Res., 20: 679-685 (1973)., N.E. Atlantic

Zooplankton, small fish, and sharks were collected from various stations in the Northeast Atlantic, stored frozen, and analyzed by neutron activation for trace metals; gas-liquid chromatography was used to detect organomercury compounds. Mercury was present in biota within the range of 0.06 to 0.38 ppm dry weight. In the decapod crustacean OPLOPHORUS, the methylmercury levels comprise 90% of the total mercury found. In SCOMBRESOX, methylmercury concentration increased with specimen size. Cadmium levels were considerably variable; a general trend toward decreasing levels in fish was observed; this trend held true for arsenic as well (av. crustacean, 25 ppm dry wt.; fish, 1.5-8.4 ppm range). Zinc concentrations were uniform and agreed with previous reports. Mercury in water samples ranged from 17-142 ppm.
MERCURY; CADMIUM; ZINC; ANTIMONY; METHYLMERCURY; ZOOPLANKTON; FISH; SHARK; CRUSTACEAN; ARSENIC

<79>
Leblanc, P.J.; Jackson, A.L., Arsenic in Marine Fish and Invertebrates., Mar. Pollut. Bull., 4(6):

<79>
<79> CONT.
88-90 (1973)., Canada

Background levels of several heavy metals, including arsenic were determined on the Pacific Coast of Canada. Higher levels of arsenic were found in marine fish (0.4-37.8 mg/kg wet wt.) than in Canadian freshwater species. Higher levels of arsenic were found in marine crustaceans than in fish from the same waters, indicating a capacity in these organisms to accumulate arsenic. Highest concentrations of arsenic were found in the Dungeness crab, CANCER MAGISTER. Arsenic in crustaceans is part of a relatively non-toxic, organic complex which accumulates in marine fish and invertebrates and may possibly have an essential biochemical function, that is, as a micronutrient.
FISH; INVERTEBRATE; ARSENIC; ACCUMULATION; CRUSTACEAN; CRAB; LOBSTER; CLAM

<80>
Lunde, G., Separation and Analysis of Organic-bound and Inorganic Arsenic in Marine Organisms., J. Sci. Food Agr., 24: 1021-1027 (1973)., Norway

Arseno-organic compounds present in marine raw materials are stable enough to withstand treatment with 6.6 N HCl at 100 deg c, while inorganic arsenic forms arsenic trichloride which volatilizes. Levels of arsenic, organic and inorganic, are reported for tissues from 12 marine species. Samples were analyzed by neutron activation analysis and X-ray fluoresence.
ARSENIC; MARINE BIOTA; ANALYSIS; ARSENO ORGANIC COMPOUND

<81>
Lunde, G., The Analysis of Organically Bound Elements (As, Se, Br) and Phosphorus in Raw, Refined, Bleached and Hydrogenated Marine Oils Produced from Fish of Different Quality., J. Amer. Oil Chem. Soc., 50: 26-28 (1973)., Norway

Marine oils obtained from herring and mackerel in various stages of spoilage show a nearly constant concentrations of arsenic and bromine, while selemium and phosphorus levels increase as the fish deteriorate. The persistence of arsenic, bromine, selenium, and phosphorus through the refining, bleaching and halogenation of fish oils was monitored through neutron activation analyses of samples at the various stages. The alkaline-refining step washes out arseno-organic compounds almost quantitatively.
FISH OILS; NEUTRON ACTIVATION; ANALYSIS; ARSENIC; SELENIUM; BROMINE; PHOSPHORUS; MACKEREL; HERRING

<82>
Lunde, G., The Analysis of Arsenic in the Lipid Phase from Marine and Limnetic Algae., Acta Chem. Scand., 26(7): 2642-2644 (1972).

Neutron activation techniques were used to determine the arsenic content and the form(s) in which arsenic occurs in the lipid phase in marine and limnetic algae. All lipid phase specimens of CHLORELLA OVALIS Butcher, CHLORELLA PYRENOIDOSA Chick, OSCILLATORIA RUBESCENS(D.C.), PHAEYDACTYLUM TRICORNUTUM Bohlin, and SKELETONEMA COSTATUM (Grev.) Cleve contained arsenic. The results are interpreted qualitatively and are said to reflect the species' relative ability to synthesize arseno organic compounds under laboratory conditions. Arsenic was found to be organically bound in these algae in the same way as in the oil phase in higher marine organisms and could, therefore, be transferred in the food chain in this form. As content of the algae ranged from 0.4 to 4.8 ppm with enrichment coefficients between 200 and 500.
ARSENIC; NEUTRON ACTIVATION; ANALYSIS; ALGA; SEAWEED

<83>
Lunde, G., Analysis of Arsenic and Selenium in Marine Raw Materials., J. Sci. Food Agr., 21: 242-247 (1970).

In order to determine the level and form of occurence of arsenic and selenium in various marine fish and other species, the water soluble phase of individual samples was fractionated by molecular gel filtration and analyzed by neutron activation. Selenium remained in a high M.W. fraction (5000) while arsenic was associated with compounds (amino acids) of lower M.W. 70-75.
ARSENIC; ANALYSIS; SELENIUM; NEUTRON ACTIVATION

<84>
Lunde, G., Analysis of Arsenic and Bromine in Marine and Terrestrial Oils., J. Amer. Oil Chem. Soc., 49(1): 44-47 (1972).

Oil from marine fish and invertebrates was homogenized, chloroform-methanol extracted, filtered, separated, centrifuged, washed, saponified, and finally extracted with diethylether. Cod liver and mackeral oils were used in fractionation experiments. Samples were analyzed for arsenic and bromine by neutron activation analysis. In general, higher levels of arsenic were found in oil than in fatty acids. Arsenic in oils ranged from 82 ppm (snail) to 4.7 ppm (lobster).
ARSENIC; BROMINE; OILS; FISH; VEGETABLE; INVERTEBRATE

<85>
Martin, J.H.; Knauer, G.A., The Elemental Composition of Plankton, Geochim. Cosmochim. Acta, 37: 1639-1653(1973)., California; Oregon

Phytoplankton samples from off the coast of California and zooplankton samples from the California and Oregon coastline and on a California-Hawaii transect were analyzed by atomic absorption spectrophotometry (AAS) for several elements including lead, cadmium, and zinc. Mercury analysis was made by flameless AAS. Phytoplankton samples were grouped according to :I) absence of titanium; II) presence of titanium; or III) strontium concentration factors greater than 2. Group II phytoplankton had the highest mean values for zinc among other elements; Group III, for cadmium, lead and mercury. Zooplankton was classified according to dominant forms present. Elemental composition for the three groups of Monteray zooplankton compared favorably with open ocean samples with respect to lead, mercury, cadmium. Zinc levels were higher, however, in the offshore groups. Microplankton from the open ocean and off Oregon were higher in lead, zinc, and mercury.
PHYTOPLANKTON; ZOOPLANKTON; LEAD; MERCURY; CADMIUM; ZINC

<86>
Matida, Y.; Kumada, H., Distribution of Mercury in Water, Botton Mud, and Aquatic Organisms of Minamata Bay, the River Agano and other Water Bodies of Japan., Bull. Freshwater Fish. Res. Lab., 19(2): 73-93 (1969)., Japan, Minamata Bay

Samples of 21 animal species, an alga (ULVA PERTUSA), and planktonic microorganisms were analyzed for mercury by atomic absorption spectrophotometry. Mercury levels ranged from 1.0 ppm (dry) in the vertebrate KONOSIRUS PUCTATUS to 279 ppm in planktonic microorganisms. Distribution of mercury in the Bay implicated the Minamata Factory of Shin-Nippon-Chisso Co. as the source of pollution.
MERCURY; MARINE BIOTA; ALGA; PLANKTON; VERTIBRATE

<87>
Miettinen, J.K.; Heyraud, M.; Keckes, S., Mercury as a Hydrospheric Pollutant. II. Biological Half-time of Methylmercury in Four Mediterranean Species: a Fish, a Crab and Two Molluscs., In:

<87> CONT.
Marine Pollution and Sea Life, Ruivo, M., (ed.), Fishing News Ltd., London., 195-198 (1970)., Ligurian Sea

SERRANUS SCRIBA (L.), CARCINUS MAENAS (L.), TAPES DECUSSATUS (L.) and MYTILUS GALLOPROVINCIALIS (Lam.) specimens were acclimatized to laboratory conditions and subsequently mercury-203 was administered as methylmercury: in fish, 1uCi CH3(203)HgNO3 per os; in crab 1uCi injected into hemolymph or by ingestion of labelled TAPES; and in molluscs 1uCi injected into foot muscle. Animals were then kept in open air aquaria provided with running sea water (salinity 37.5 ppth, temperature 17-23 degrees C for 99 days). Loss of mercury in all species had a rapid and a slow component, the latter determining biological half-life: fish (SERRANUS) 267 days; crab (CARCINUS) 400 days (injected); mollusc (TAPES) 481 days; mollusc (MYTILUS) 1,000 days. Mercury administered by injection is eliminated more slowly than that given orally.
MERCURY; UPTAKE; FISH; CRAB; MOLLUSC; ELIMINATION; MERCURY-203

<88>
Mishima, J.; Odum, E.P., Excretion Rate of Zn-65 by LITTORINA IRRORATA in Relation to Temperature and Body Size., Limnol. Oceanogr., 8: 39-44(1963).

Snails were collected from a salt marsh, placed in glass bowls; and fed a suitable natural diet onto which about 5 uCi of zinc-65 had been applied by pipette. After 24 hrs snails were counted for radioactivity and placed in a clean, non-radioactive enviornment either in the laboratory under controlled temperature condition (15, 25 or 30 deg C) or in the field. Snails in the laboratory were moved to clean bowls every 2-3 days and all snails were monitored for a 39 day period. Loss rate was rather rapid during the first 10 days, slower in the next phase, and at the end of the 39 days may have been entering a third, slower stage. The biological half-life of zinc was inversely related to body size, directly related to environmental temperature. Both effects were significant.
EXCRETION; ZINC; TEMPERATURE; SIZE; SNAIL

<89>
Nuzzi, R., Toxicity of Mercury to Phytoplankton., Nature, 237: 38-40 (1972).

Phenylmercuric acetate (PMA) is inhibitory to three phytoplankton species at low concentrations (0.06 ug/l). PHAEODACTYLUM TRICORNUTUM, CHLORELLA SP. (Hudson River) and CHLAMYDOMONAS SP. (Block Is. Sound) were grown and tested axenically in chemically defined medium DC. Mercuric chloride (0.74 ug Hg/L to 66.6 ug Hg/L) or PMA (0.06 ug Hg/L to 15.0 ugHg/L was added to the growth media. After 16 days, cells were counted on a Coulter Counter Model B. PMA is more toxic than HgCl2; phenylacetate does not effect growth in P. TRICORNUTUM. The inhibitory effect of PMA (3 ug Hg/L) on P. TRICORNUTUM was almost completely reversed by the addition of 5 mg % glutathione.
MERCURY; PHYTOPLANKTON; TOXICITY

<90>
O'Hara, J., Cadmium Uptake by Fiddler Crabs Exposed to Temperature and Salinity Stress., J. Fish. Res. Board Can., 30(6): 846-848 (1973)., South Carolina, Georgetcwn

Crabs were exposed to combinations of 33, 25, or 10 deg C and 30 or 10 ppth salinity. One microcurie of cadmium-109 and 10 ppm cadmium as CdCl2 were added to each test chamber. Four active animals in each chamber were removed at 24, 48, and 72 hr. Cadmium is absorbed at an elevated rate in a low salinity environment at all temperatures due to the active uptake of salts to maintain osmotic pressure. At the higher temperatures the transfer of cadmium from gill to hepatopancreas is more rapid. Cadmium accumulates at a higher rate at higher temperatures leading to earlier mortality.
CADMIUM; UPTAKE; CRAB; TEMPERATURE; SALINITY

<91>
O'Hara, J., The Influence of Temperature and Salinity on the Toxicity of Cadmium to the Fiddler Crab, UCA PUGILATOR., Fish. Bull., 71(1): 149-153 (1973).

Crabs were exposed to combinations of 10,20, or 30 ppth, salinity in water maintained at 10, 20, or 30 deg C. To these test chambers, 1.0, 5.0, 10.0, 25.0, or 30 ppm was added. Higher temperatures and lcwer salinities increase cadmium toxicity. At 30 deg C in a 10 ppth salinity environment, the concentration lethal to 50% of the organisms in 240 hr (TLM-240 hr.) was 2.9 ppm cadmium. Cadmium levels were estimated in tissues by spiking cadmium stock solutions with cadmium-109. Tissues (hepatopancreas, gill, green gland, and thoracic muscle) taken at 0, 12, 24, 36, 48, and 60 were wet ashed and radioactivity was measured. Gill tissues accumulated cadmium in the first 12 hr. to 4 times the level in the surrounding water; hepatopancreas, 2 times; and green gland, 12 to 20 times. Muscle did not accumulate cadmium in the time period examined.
CADMIUM; CRAB; TOXICITY; TEMPERATURE; SALINITY

<92>
Olson, K.R.; Harrel, R.C., Effect of Salinity on Acute Toxicity of Mercury, Copper, and Chrcmium for RANGIA CUNEATA (Pepecypoda, Mactridae)., Contrit. Mar. Sci., 17: 9-13 (1973).

Clams were exposed for 4 days to salinities of 1.0, 5.5, or 22 ppt at 24 deg C and test solutions of mercury, copper, or chromium salts of several concentrations. The 48, 72, and 96 hr median tolerance limits (TLm) were determined for each of the metals by Standard Methods. Salinities chosen are within the normal environmental range for this species. The lowest TLm for mercury was less than 1.0 ppth salinity (6.3 ppm for 48, 5.5 for 72, and 5.1 for 96 hr.) the highest, at 5.5 (40.0 ppm for 48, 20 for 72, and 10 for 96 hr). In freshwater mercury concentrations of 6 ppm are required to establish a 48 hr TLm.
MERCURY; TOXICITY; COPPER; CHROMIUM; CLAM; BRACKISH WATER

<93>
Peden, J.D.; Crothers, J.H.; Waterfall, C.E.; Beasley, J., Heavy Metals in Somerset Marine Organisms., Mar. Pollut. Bull., 4(1): 7-9 (1973).

Limpets (PATELLA VULGATA) from eleven sites along the Somerset coast and four locations in Devon were collected and analyzed for arsenic, cadmium, copper, lead, mercury, and zinc by atomic absorption spectrophotometry. A gradient of cadmium concentrations toward a peak at Avonmouth was found; zinc and cadmium levels are inversely related. Ranges of metal levels (ppm wet weight) from somerset sites are: arsenic 1.0-3.9; cadmium 10.3-118.5; lead 0.17-0.75; mercury 0.06-0.31; and zinc 48.2-129.0. Cadmium concentration correlated with size, a reflection of the amount of food consumed, not age. Depletion experiments and crabs and limpets maintained in "fresh" unpolluted seawater for 7 weeks show almost no cadmium loss, but considerable zinc losses. Limpets and dog whelks which feed on limpets were examined to determine possible bioconcentration of zinc and cadmium up the food chain. Cadmium bio-magnification was obvious; zinc, less so. Fish and shrimp caught (for human consumption) off the Somerset coast had the following ranges of cadmium (Cd) and zinc (Zn) levels: fish (Cd) 0.06-1.67, (Zn) 4.0-52.5; shrimp (Cd) 2.8-4.4, (Zn) 35.5-81.7.
ESTUARY; LIMPET; FISH; SHRIMP; CADMIUM; LEAD; ARSENIC; MERCURY; ZINC; DOG WHELK

<94>
<94>
Penrose, W.R., Arsenic in the Marine and Aquatic Environments: Analysis, Occurrence, and Significance., CRC Critical Reviews in Environmental Control, 4(4): 465-482(1974).

Throughout centuries the toxicity of arsenic has been recognized. This property has lead to its use in medicine, agriculture, and warfare. It has recently been named as a suspected carcinogen. Literature dealing with the analysis occurrence and significance of arsenic in marine and aquatic environments is presented.
REVIEW; ARSENIC

<95>
Pentreath, R.J., The Accumulation from Water of 65 Zn, 54 Mn, 58 Co and 59 Fe by the Mussel, MYTILUS EDULIS., J. Mar. Biol. Assoc. U.K., 53: 127-143 (1973)., England, Lowestoft

Mussels were maintained in filtered sea water (2 uM) at 10 deg C without food. Paired isotope concentrations each maintained at 1 uCi/l were: zinc-65/manganese-54 and iron-59/cobalt-58. Concentration factors for zinc 65 (uCi of tissue/uCi of water) for various tissues ranking from the highest are: gill, stomach, mantle, foot, gonad, and adductor.
BIOACCUMULATION; ZINC-65; COBALT-58; IRON-59; MANGANESE-54; MUSSEL

<96>
Pentreath, R.J., The Accumulation from Sea Water of 65Zn, 54Mn, 58Co and 59Fe by the Thornback Ray, RAJA CLAVATA L., J. Exp. Mar. Biol. Ecol., 12: 327-334 (1973)., England, Lowestoft

The radionuclides, as chloride salts, were added to seawater in pairs to give a final concentration of 1 uCi/L.--zinc and manganese, cobalt and iron. Tissue samples were analyzed by gamma-spectrometry. Over time (84 days) accumulation of the four nuclides follow essentially the same pattern; the metals in order of decreasing concentration factor over this period are: iron-59, zinc-65, cobalt-58, and manganese-59. Zinc-65 concentration capacities of tissues in decreasing order are: cartilage, liver, spleen, gut, skin, kidney, gill, gonad, heart, rectal gland, muscle, and whole blood.
RAY; ZINC-65; MANGANESE-54; COBALT-58; IRON-59; BIOACCUMULATION

<97>
Peterson, C.L.; Klave, W.L.; Sharp, G.D., Mercury in Tunas: A Review., Fish. Bull., 71(3): 603-613 (1973).

This review (37 current references) on mercury in larger marine fish, specifically tuna, discusses: Sources of Mercury in the Marine Environment; Mercury in Fishes; Levels of Mercury in Tunas and Other Large Pelagic Fishes; Relationship Between Mercury Levels and Fish Size; Geographic Variation in Mercury Content of Fishes; Mercury Contamination and Toxicology; Mercury Poisoning and its Effects; and Mercury Standards for Fish and Fish Products. The current Food and Drug Administration's (FDA) "in house" standard of 0.5 ppm is considered adequate to insure public health and safety.
TUNA; SWORDFISH; MERCURY; FOODSTUFF

<98>
Portmann, J.E., Monitoring Metals in Marine Animals., Mar. Pollut. Bull., 2(10): 157-158 (1971)., England; Wales

Samples of food fish (liver and muscle) and shellfish (soft parts) collected from inshore and offshore sites in England and Wales since July 1969, were analyzed by atomic absorption spectrophotometry for cadmium, chromium, copper, lead, mercury, and zinc. Fish within a species from a given area are relatively consistent in levels of trace metals; there is also little difference among species from the same region. Metal concentrations in fish livers were typically 2-5 times those in muscle. Shellfish showed side variation within and among species and typically considerable ranges of metal concentrations for shellfish from a given area.

<99>
Portmann, J.E.; Riley, J.P., Determination of Arsenic in Sea Water, Marine Plants and Silicate and Carbonate Sediments., Anal. Chim. Acta, 31: 509-519 (1964).

To recover and measure microgram quantities of arsenic from marine plants, an analylic method was developed based on nitric acid digestion, cocrystallization with thionalide, and photometric determination by molybdenum blue. Replicate analyses on an air-dried, well-washed specimen of FUCUS SERRATUS showed arsenic to be present at a concentration of 1.67 ug/g. Recovery was calculated at 95 per cent.
ARSENIC; SEA WATER; MARINE PLANTS; SEDIMENT; ANALYSIS; COCRYSTALLIZATION; ALGA; SPECTROPHOTOMETRY

<100>
Preston, A., The Concentration of 65 Zn in the Flesh of Oysters Related to the Discharge of Cooling Pond Effluent from the C.E.G.B. Nuclear Power Station at Bradwell-on-Sea, Essex., In "Radioecological Concentration Processes," Aberg, B. and Hungate, F.P., eds. Proc. Int. Symposium, Stockholm, April 25-27, 1966, Pergamon Press, New Ycrk., 995-1004 (1967)., England, Essex, Bradwell-on-Sea

Special layings of Portuguese (CRASSOSTREA ANGULATA) and native oysters (OSTREA EDULIS) were made at the power station cooling water outfall. Other samplings at commercial beds in the estuary were established. The average rate of zinc-65 discharge throughout sampling was 16.6 mCi/mo.; oysters samples had been "resident" for at least 3 mcs. The concentration of zinc-65 in oyster flesh as pCi/g wet wt.(c) related to distance in miles (D) is represented as C=1.43 X D to the 0.91 power. The data reflect the combined effect of radionuclide dispersion and reconcentration by oysters. Over the sampling period, levels of zinc-65 and stable zinc increased in oyster flesh; the stable zinc increase is believed not tc have had a significant effect on the concentration of zinc-65 by oysters. The relationship between stable zinc content (C) in Portuguese oysters and dry weight of soft parts (W) is expressed as C=KxW to the 0.5 power.
ZINC; OYSTER; NUCLEAR POWER PLANT

<101>
Preston, A., Cadmium in the Marine Enviroment of the United Kingdom., Mar. Pollut. Bull., 4(7): 105-107 (1973)., United Kingdom

Atmospheric input of cadmium into ocean surface water is significant, particularly in inshore waters. Even with relatively large cadmium concentration factors in many marine organisms, the major reserves of cadmium in the marine ecosystem lie in bed sediments. Release of cadmium from these stores occurs continually. Ocean residence time is estimated as 10,000 years. If all the mined cadmium were lost to the sea--nearly 10,000 tons per year--the cadmium ocean level would increase by 10% in 7,000 years.
CADMIUM; ALGA; SHELLFISH; FISH

<102>
Preston, A.; Jefferies, D.F.; Dutton, J.W.R.; Harvey, B.R.; Steel, A.K., British Isles Coastal Waters: The Concentrations of Selected Heavy Metals in Sea Water, Suspended Matter and Biological Indicators - A Pilot Survey., Environ. Pollut., 3: 69-82 (1972).

<102> CONT.
Surface and subsurface water samples and samples of seaweed (FUCUS VESICULOSIS), laverweed (PORPHYRA UMBILICALIS) and limpets (PATELLA VULGATA) were taken from six sea water stations in the British Isles. Water was analyzed for zinc, copper, iron, manganese, nickel, silver, cadmium and lead by neutron activation analysis. Biological materials were analyzed by atomic absorption spectrophotometry. High levels of copper and zinc in water were found in specific areas. In suspended matter, the highest mean concentrations for all metals except cadmium were found in the eastern Irish Sea; the highest levels of cadmium was in samples from the North Sea. Only cadmium contamination in the open Atlantic is significantly higher than at other sampling stations. In general, levels of metals in biological material reflected the levels in the sea water from that area.
ZINC; COPPER; MANGANESE; NICKEL; SILVER; CADMIUM; LEAD; ALGA; LIMPET; PORPHYRA; SEAWATER PLANTS

<103>
Pringle, G.H.; Hissong, D.E.; Katz, E.L.; Mulawka, S.T., Trace Metal Accumulation by Estuarine Mollusks, J. Sanit. Eng. Div., Amer. Soc. Civil Eng., 94(SA3): 455-475 (1968)., Maine; North Carolina; Washington

Two clam and two oyster species were collected from Atlantic and Pacific sampling stations. Specimens were shucked and analyzed by atomic absorption spectrophotometry. Ranges of metal concentrations (ppm wet weight) found are: zinc-oyster (Atlantic) 180-4120, oyster (Pacific) 86-344, soft shell clam 9.0-28, Northern Quahaug 11.50-40.20; lead-oyster (A) 0.10-2.30, oyster (P) 0.10-4.50, soft shell clam 0.10-10.20, Northern Quahang 0.10-7.50; cadmium-oyster (A) 0.10-7.80, oyster (P) 0.20-2.10, soft shell clam 0.10-0.90, Northern Quahaug 0.10-0.73. Some specimens were held in a continuous flow seawater system 1) in which 0.2, 0.1, 0.05, and 0.025 ppm lead levels were maintained over a ten week period and 2) in which levels of metals in the seawater are minimal. Lead accumulation in oyster after 10 days (first case) was from 24 to 203 ppm. Initial and final depletion ranges in these specimens were dependent upon a prior accumulation rate determined previously by exposure to lead concentrations. Depletion ranges for "naturally" exposed quahaug were: initial 38 mg/kg/day; final 26 mg/kg/day; rate 0.12 mg/kg/day.
OYSTER; CLAM; QUAHAUG; ZINC; IRON; COPPER; NICKEL; COBALT; MANGANESE; LEAD; CADMIUM; CHROMIUM

<104>
Pyefinch, K.A.; Mott, J.C., The Sensitivity of Barnacles and their Larvae to Copper and Mercury., J. Exp. Biol., 25: 276-298 (1948).

Toxicity of copper and mercury to acorn barnacles at various stages of their life cycle was studied. Animals were exposed for six hours. to various concentrations of cupric sulfate or mercuric chloride within the range necessary to produce 0 to 100 per cent mortality. Sublethal effects on settlement and metamorphosis were observed in cyprids. Marked differences in relative sensitivity were observed between the two barnacle species, and among the various stages within species. Diluted sea water reduces the effect of both metal salts on the free-swimming cyprid.
MERCURY; COPPER; TOXICITY; BARNACLE; LARVA

<105>
Renfro, W.C., Transfer of 65 Zn from Sediments by Marine Polychaete Worms., Mar. Biol., 21: 305-316 (1973)

A small flowing seawater system simulating the water-sediment interface of an estuary or nearshore coastal environment was designed to allow sampling from each compartment. Zinc-65 spiked sediments lost little activity to seawater (1-3 percent in 18 days; 3-9 per cent in 30 days). Burrowing by NEREIS DIVERSICOLOR increased zinc-65 desorption from sediments 3-7 times. Over five days the worm takes up about 0.2% of the total zinc-65 present. Steady state conditions are approached at day 60. Biological half-life under these experimental conditions was approximately 14-17 days during the loss period day 3-15 but varies greatly according to the interval observed.
POLYCHAETE WORM; ZINC-65; TRANSFER; SEDIMENT

<106>
Riley, J.P.; Segar, D.A., The Distribution of the Major and Some Minor Elements in Marine Animals. I. Echinoderms and Coelenterates, J. Mar. Biol. Assoc. U.K., 50: 721-730 (1970).

Samples of Echinodermata, (ASTERIAS RUBENS, SOLASTER PAPPOSUS, PORANIA PULVILLUS, HENRICIA SANGUINOLENTA, an unidentified Ophiuroid, ECHINUS ESCULENTUS, SPATANGUS PURPUREUS) and Coelenterata (TEALIA FELINA and ALYCONIUM DIGITATA were analyzed by atomic absorption spectrophotometry for various elements including cadmium, zinc, and lead. Considerable variation in trace element levels was found in the echinoderms. Aboral skin of ASTERIAS contained more than twice the levels of cadmium as oral skin. In general, the less calcified body parts in this organism were richer in trace metals. Trace element content of the pyloric caeca was below those reported for digestive organs of marine invertebrates. Relatively high zinc content was found in the oral shell of ECHINUS. In this species concentrations of different trace elements occurred in the upper or lower halves of the shell--zinc, cadmium, and copper were present particularly in the upper halves. Highest trace element levels in ECHINUS occurred in the intestine, zinc and cadmium were definitely enriched. In the Coelenterates, zinc was abundant in TEALIA; Cadmium and lead in ALYCONIUM.
ECHINODERM; COELENTERATE; ZINC; CADMIUM; BIOACCUMULATION; LEAD; DISTRIBUTION

<107>
Rivers, J.B.; Pearson, J.E.; Shultz, C.D., Total and Organic Mercury in Marine Fish., Bull. Environ. Contam. Toxicol., 8(5): 257 - 266 (1972)., Hawaii

Skinless fish fillets were homogenized and samples split for analysis of either total or organic mercury by flameless atomic absorption spectrophotometry. Because recovery decreased for high concentrations of organic mercury, small sample sizes were used. Except for the Pacific Blue Marlin, close correlation exists between total and organic mercury levels. Pelagic species had high levels of total and organic mercury; inshore fish exhibited lower levels. No obvious relationship between weight and mercury levels were observed. Mercury levels in the Pacific Blue Marlin, both organic and total, were highest (0.58 ppm and 7.57 ppm).
MERCURY; FISH

<108>
Schulz-Baldes, M., The Common Mussel MYTILUS EDULIS as Indicator for the Lead Concentration in the Weser Estuary and German Bight., Mar. Biol., 21(2): 98-102 (1973)., Germany, Weser Estaury and German Bight

Mussels were collected at 13 stations along the Weser Estuary and German Bight and soft tissue samples were analyzed by atomic absorption spectrophotometry for lead. Levels ranged from 6.4 ug/g dry weight at Bremerhaven to 1.9 ug/g at Helgoland. Unpublished data show that mussels reflect the concentration of lead in their environment. The gradient in lead levels in mussels for this study reflect sampling in heavily polluted to lesser polluted areas in the German Bight.
LEAD; MUSSEL; ESTUARY; POLLUTION INDICATOR

<109>
<109>
Segar, D.A.; Collins, J.D.; Riley, J.P., The Distribution of the Major and Some Minor Elements in Marine Animals. Part II. Molluscs., J. Mar. Biol. Assoc. U.K., 51: 131-136 (1971)., Irish Sea

Samples of PECTEN MAXIMUS, CHLAMYS OPERCULARIS, GLYCYMERIS GLYCYMERIS, MODIOLUS MODIOLUS, PATELLA VULGATA, NUCELLALAPILLUS, MYTILIS EDULIS, CARDIUM EDULE, MERCENARIA MERCENARIA, BUCCINUM UNDATUM, CREPIDULA FORNICATA, and the freshwater ANODONTA SP. were analyzed for elemntal composition other than iron, magnesium, and zinc, values for all the marine species except PATELLA VULGATA were similar to within an order of magnitude. Differences seemed to reflect environment rather than species specifity. Wide variation among individuals was observed. In CREPIDULA and MODIOLUS, particularly, high concentrations of cobalt, nickel, and zinc occurred. In PECTEN enrichment occurred to a moderate degree in mantle, gills and gonads. Data are presented in tabular format: elemental composition of the shells and of the entire soft parts of some molluscs, of PECTEN MAXIMUS, and of MODIOLUS MODIOLUS.
MOLLUSC; IRON; MANGANESE; COBALT; NICKEL; CADMIUM; COPPER; LEAD; ZINC; SILVER; CHROMIUM; ALUMINUM; SODIUM; POTASSIUM; CALCIUM; MAGNESIUM; STRONTIUM; PHOSPHORUS

<110>
Sergeant, D.E.; Armstrong, F.A.J., Mercury in Seals from Eastern Canada., J. Fish. Res. Board Can., 30(6):843-846 (1973)., Canada, East coast

Tissue samples were taken from four species of Canadian seals: grey (HALICHOERUS GRYPUS) and harbour (PHOCAVITULINA), both resident; hood (CHRYSTOPHORA CRISTATA) and harp (PAGOPHILUS GROENLANDICUS), both migratory. Mercury was determined by atomic absorption spectrophotometry. A high correlation was observed between seal age and liver mercury concentrations, especially in grey seals. Muscle, kidney, and hair levels were proportionately lower. Liver to muscle ratios were high in all adult seals. About 5 percent of liver mercury was methylmercury. Lower mercury levels in harp seals versus the resident species may be due to diet rather than pollution.
MERCURY; SEAL; BIOACCUMULATION

<111>
Seymour, A.H., The Rate of Loss of Mercury by Pacific Oysters., In: Mercury in the Western Environment. Buhler D.R. ed. Proc. of a Workshop, Portland, OR, Continuing Education Publications, Corvalis, O.R., 85-90 (1971)., Washington, Hood Canal

Nine adult oysters (CRASSOSTREA GIGAS) were coated with paraffin and placed in an aquarium containing 3 L. seawater and 2.7 uCi of mercury-203. After 20 hours exposure, oysters were removed to an aquarium in which water was replaced daily with fresh sea water. Nine days later the oysters were returned to their natural habitat; subsequently, radioactivity measurements were made periodically. Paraffin coating insured that measurements reflected mercury levels in flesh, not adsorbed onto the outer shell. Loss of mercury was exponential. Decay curves can be divided into four linear segments for the periods: 1-2 days; 2-9 days; 9-32 days; and 32-133 days. The consistent increase in biological half-life over the 133 day period suggests a characteristic rate of loss for several compartments in this organism.
MERCURY; BIOLOGICAL HALF-LIFE; OYSTER

<112>
Simpson, R.E.; Horvitz, W.; Roy, C.A., Survey of Mercury Levels in Fish and Other Foods., Pestic. Monit. J., 7(3): 127-138 (1974).

Mercury levels were determined for a variety of canned fish samples for a 3 yr period from 1970-1972. Most samples were analyzed by atomic absorption spectrometry, but neutron activation analysis was used to confirm low values. Over 3,000 samples of tuna showed an overall average of 0.25 ppm. Less than 4% of the samples exceeded the FDA guideline of 0.5 ppm: Halibut (500 samples) averaged 0.25 ppm with 13% of the samples over the 0.5 ppm guideline; swordfish (853 samples), 95% over 0.5 ppm and 50% over 1.0 ppm.
MERCURY; TUNA; SWORDFISH; HALIBUT; FOODSTUFF

<113>
Somayajulu, B.L.K.; Rama, Mercury in Sea-Food from the Coast off Bombay., Curr. Sci. (India), 41(6): 207-208 (1972)., India, Bombay

Samples of lobster and several fish species were analyzed by neutron activation. Out of samples from 7 species mercury levels in 6 ranged from 62-130 ppb (fresh weight), but salmon (tail portion) had 470 ppb. These levels represent concentration factors of 5 to 20 times. Only salmon approaches the U.S. upper limit for seafood.
MERCURY; FISH; LOBSTER

<114>
Stenner, R.D.; Nickless, G., Absorption of Cadmium, Copper and Zinc by Dog Whelks in the Bristol Channel., Nature, 247: 198-199 (1974)., Dorset (Beer); North Somerset (St. Andrews Head)

Dog whelks (NUCELLA LAPILLUS) were collected from Beer in Dorset, a relatively unpolluted area. A few samples were analyzed, while most of the specimens were transferred to another natural location, a polluted area. Subsequently this group was sampled over a five month period and analysis for cadmium, copper, and zinc was by atomic absorption spectrophotometry. Mean concentrations of cadmium rose from 36 to 211 ppm dry weight; zinc, 345 to 2530. Dog whelks indigenous to the polluted area analyzed for cadmium and zinc showed mean levels (ppm dry weight) of 780 and 2,900.
DOG WHELK; ABSORPTION; CADMIUM; COPPER; ZINC

<115>
Suzuki, T.; Miyama, T.; Toyama, C., The Chemical Form and Bodily Distribution of Mercury in Marine Fish., Bull. Environ. Contam. Toxicol., 10(6): 347-355 (1973)., Sea of Japan; China Sea

Duplicate samples of muscle, liver, brain, kidney, and stomach contents from 13 species from the China Sea and the Sea of Japan were analyzed by cold atomic absorption photometry for inorganic and total mercury. Except in fish from the Sea of Japan, a good correlation was seen between mercury levels and body weight; liver and kidney levels were higher than those in muscle. Stomach contents, a measure of mercury levels in the surrounding medium, were markedly higher in greenlings from the Sea of Japan than from fish from the China Sea. The concentration ratio between gastric contents and 1) muscles for total mercury is less than 2, 2) muscle for inorganic mercury is 0.1, 3) liver for total and inorganic mercury is 15. The kidney accumulates inorganic mercury selectively.
MERCURY; BIOACCUMULATION; FISH

<116>
Tennant, D.A.; Forster, W.O., Seasonal Variation and Distribution of Zinc-65, Manganese-54, and Chromium-51 in Tissues of the Crab CANCER MAGISTER Dana., Health Phys., 18(6): 649-657 (1969)., Oregon, Columbia River

During 1966-1967 the tissues exoskeleton, mouth parts, endophragmal skeleton, gills, stomach, soft shell, hepatopancreas, and muscle of crabs were taken from the Columbia River estuary below the Hanford Reactor. Ashed samples were analyzed for total elements and radioactive nuclides. Results show: a linear relationship between specific

<116> CONT.
activity and radioactivity; in many cases these peaks coincide with large discharges to the river; manganese-54 contributes little to tissue radioactivity, compared to zinc-65 (in soft tissues) and chromium-51 (in calcareous tissues). Manganese-54 is adsorbed onto the surface (exoskeleton, setae, and mouth parts); chromium-51 and zinc-65 are taken up by rapidly metabolizing tissues to a greater extent than by inert tissues.
SEASONAL VARIATION; ZINC-65; MANGANESE-54; CHROMIUM-51; CRAB; DISTRIBUTION; ESTUARY

<117>
Unlu, M.Y.; Heyraud, M.; Keckes, S., Mercury as a Hydrospheric Pollutant. I. Accumulation and Excretion of 203-Hg Cl2 in TAPES DECUSSATUS L., In: Marine Pollution and Sea Life, Ruivo, M., (ed.), Fishing News Ltd., London., 292-295 (1970).

Animals were maintained in natural sea water with salinity at 37.5 ppt and temperature at 15 deg C for the accumulation phase; in sea water from a laboratory system at 20-23 deg C for the loss phase. Mercury-203 was accumulated from sea water by ingestion of labeled PHAEODACTYLUM or introduced by injection of 203 Hg Cl2 (21nCi) into the foot muscle of TAPES. Rapid uptake occurred from sea water; within one day the TAPES mercury-203 level was 10 times that in the surrounding water. Accumulation decreased subsequently due to decreased availability of mercury-203. Gills and viscera had the highest mercury levels. Surface adsorption accounts for only a small portion of the uptake. The biological half-time is estimated table 7 to 10 days regardless of accumulation rate from sea water (1, 7, or 14 days); 5 days for accumulation through ingestion; and 481 for injected animals.
MERCURY; UPTAKE; ELIMINATION; BIOLOGICAL HALF-TIME; TAPES; ALGA

<118>
Vernberg, W.B.; DeCoursey, P.J.; Padgett, W.J., Synergistic Effects of Environmental Variables on Larvae of UCA PUGILATOR., Mar. Biol., 22(4): 307-312 (1973)., South Carolina

Larvae maintained in one of the following conditions of temperature (deg C) and salinity (ppth): 20/20; 20/30; 30/20, or 30/30 were exposed to either 0.0 or 1.8 ppb mercury. Mortality rates at 96 hr. metabolic rates, and phototactic responses were measured. Larvae exposed to mercury in the 30/20 regime showed a 20 per cent increase in mortality over controls. At the low temperature, mercury exposed larvae showed highest mortality at either salinity level. At high temperatures mercury depressed metabolic rate at either salinity level; at low temperature mercury enhanced metabolism. Mercury exposed larvae in either the 20/30 or 20/20 regimes were more photoreactive than controls.
TOXICITY; MERCURY; CRAB; LARVA

<119>
Vernberg, W.B.; O'Hara, J., Temperature-Salinity Stress and Mercury Uptake in the Fiddler Crab, UCA PUGILATOR., J. Fish. Res. Board Can., 29(10): 1491-1494 (1972)., South Carolina, Georgetown

Crabs were collected and acclimated to 30 ppth salinity and 25 deg C on a 12 hr light: 12 hr dark schedule. Subsequently crabs were exposed tc 0.18 ppm mercury as mercuric chloride with 1 uCi 203 Hg under regime conditions of 33, 25, or 5 deg C and 5 or 30 ppth salinity. No correlation between sex and mercury uptake was observed. Gill tissue accumulated more mercury than hepatopancreas or any other tissue in all test envionments. Accumulation occurred rapidly (82% in 24 hr) and continued through 48 and 72 hr except in crabs in the 5 deg C, 5 ppth salinity environment where mercury levels began to fall after 72 hrs. Accumulation in gill for the first 24 hr was significantly higher in the 5-5 (temperature-salinity) crabs than in 5-30 crabs, which in turn was significantly higher than all other 30 ppth groups. Conditions of low salinity and low temperature increased mercury accumulation in gill. Accumulation in the hepatopancreas, however, was directly related tc temperature.
TEMPERATURE; SALINITY; UPTAKE; MERCURY; CRAB

<120>
Vernberg, W.B.; Vernberg, J., The Synergistic Effects of Temperature, Salinity, and Mercury on Survival and Metabolism of the Adult Fiddler Crab,UCA PUGILATOR., Fish. Bull., 70(2): 415-420 (1972)., South Carolina, Georgetown

Crabs were collected and held at optimal laboratory conditions (30 ppth salinity, 25 deg C) before sexed groups were exposed to 1) 0.18 ppm mercury; 2) 5 ppth salinity and 5 deg C alcne, or plus mercury; 3) 5 ppth salinity and 35 deg C alone, or plus mercury. With mercury alone no increased mortality occurred, but metabolic rate, especially in males, was somewhat decreased. Conditions of low salinity were stressful to crabs, the lower temperature was more conductive to stress effects than the higher. Mortality and depression of metabolism caused by mercury exposure were enhanced by either of these conditions. Females survived longer and were able to maintain higher metabolic rates under all conditions.
MERCURY; CRAB; SALINITY; TEMPERATURE; STRESS

<121>
Westoo, G., Methylmercury as Percentage of Total Mercury in Flesh and Viscera of Salmon and Sea Trout at Various Ages., Science, 181:567-568 (1973)., Sweden

Muscle and viscera from salmon and sea trout were sampled and analyzed for total- and methylmercury by neutron activation and gas chrcmatography respectively. Ages of cultured salmon were known but 1- and 2-year-old salmon and sea trout had to be estimated. Mercury concentration increases roughly with age; most of the mercury in muscle is in the form of methylmercury, regardless of age. In viscera, 26 to 67 percent of mercury occurred as methylmercury with no dependence on age.
METHYLMERCURY; FISH; AGE; SALMON; SEA TROUT; MERCURY

<122>
Williams, P.M.; Weiss, H.V., Mercury in the Marine Environment: Concentration in Sea Water and in a Pelagic Food Chain., J. Fish. Res. Board Can., 30(2): 293-295 (1973)., California, San Diego

Zooplankton, bathypelagic fish, crustacea, benthic organisms, a squid, and a skipjack tuna as well as sediment and sea water samples were collected and analyzed for mercury by neutron activation analysis. Mercury levels in collected organisms: zooplankton (30-500 m depth) 55-123 pbb, (1200-3200 m) 189-388 ppb; hatchet fish, snipe eel, CYCLOTHONES, decapods, nysid, and NANSENIA 122-406 ppb; squid and brittle star 280 ppb; skipjack tuna 720 ppb and BATHYLOGUS SP. 2800 ppb. Mercury present in sea water at 100 m was 270 parts per trillion (ppt); mixed layer 95 ppt; from 210-4080 m 42 ppt (av.) The higher concentration of mercury in surface water in probably due to atmospheric influx, most likely not due to biological activity.
MERCURY; FOOD CHAIN; FISH; PLANKTON; BENTHOS; CRUSTACEAN; SEDIMENT; EEL; ECHINODERM

<123>
Windom, H.; Stickney, R.; Smith, D.; Taylor, F., Arsenic, Cadmium, Copper, Mercury, and Zinc in Some Species of North Atlantic Finfish., J. Fish. Res. Board Can., 30(2): 275-279 (1973)., North Atlantic Ocean

Species of inshore and offshore fish were caught and analyzed for arsenic, cadmium, copper, and zinc

<123>
<123> CONT.
by atomic absorption spectrophotometry (AAS) and mercury by cold vapor AAS. Few of the samples contained arsenic above the sensivitiy range, but of these, concentrations were up to 6.4 ppm. Except for planktivorous species, which concentrate metals, levels of cadmium, copper, and zinc appear similar in all species examined. In CHONDRICHTHYS muscle, copper, zinc and, perhaps, mercury levels are about the same as in OSTEICHTHYS, whereas arsenic is at higher levels. The liver in CHONDRICTHYS contains higher levels of arsenic, cadmium, copper, and zinc than any other organ or muscle; reproductive organs, embryos, or pups may concentrate zinc slightly. No correlation was observed between the sampling location (inshore or offshore) and elemental composition.
ARSENIC; CADMIUM; COPPER; MERCURY; ZINC; FINFISH

<124>
Windom, H.L.; Smith, R.G., Distribution of Iron, Magnesium, Copper, Zinc, and Silver in Oysters along the Georgia Coast., J. Fish. Res. Board Can., 29(4): 450-452 (1972)., Georgia

Oysters from 10 stations of various salinity ranges were shucked and the shell and soft parts analyzed for iron, magnesium, copper, zinc and silver by atomic absorption spectrophotometry. Except for manganese, metal levels were higher in soft tissues. Correlations exist between silver, copper, and zinc as well as between manganese and iron. The geochemistry of a particular metal is an important consideration in its uptake by oyster.
IRON; COPPER; ZINC; SILVER; OYSTER

<125>
Wisely, B.; Blick, R.A.P., Mortality of Marine Invertebrate Larvae in Mercury, Copper, and Zinc Solutions., Aust. J. Mar. Freshwater Res., 18: 63-72 (1967).

WATERSIPORA CUCULLATE (Busk), BUGULA NERITINA L., SPIRORBIS LAMELLOSA Lamark, GALEOLARIA CAESPITOSA Lamark, MYTILUS EDULIS PLANULATUS Lamark, CRASSOSTREA COMMERICALIS Iredale and Roughley, and ARTEMIA SALINA L. larvae were obtained from various sources; toxic concentrations of metals were added to determine lethality. Species arranged in order of decreasing sensitivity to the metals are: zinc-WATERSIPORA, SPIROBIS, BUGULA; Copper-MYTILUS, GALEOLARIA, BUGULA, SPIRORBIS, WATERSIPORA; mercury-ARTEMIA, CRASSOSTREA, MYTILUS, BUGULA; GALEOLARIA; WATERSIPORA; SPIRORBIS.
TOXICITY; BRYOZOAN; TUBEWORM; MOLLUSC; SHRIMP; MERCURY; ZINC; COPPER; LARVA

<126>
Wolfe, D.A., Levels of Stable Zn and 65 Zn in CRASSOSTREA VIRGINICA from North Carolina., J. Fish. Res. Board Can., 27(1): 47-57 (1970)., North Carolina, Beaufort

Oysters were captured external surfaces washed, and were shucked accumulated radioactivity was measured by scintillation counting and stable zinc by atomic absorption spectroscopy or neutron activation analysis. Absolute and specific activities declined during the sampling period; total zinc levels increased slightly but varied considerably (av. 241 ppm/wet wt.) . Absolute activity half-removal time is 347 days; specific activity, 276 days. The ecological half-time reported is longer than the physical half-life of zinc 65 (245 days); reasons for this are discussed. Zinc localizes in soft parts; these values averaged 6 times the levels in shells.
ZINC; ZINC-65; OYSTER; ESTUARY; DISTRIBUTION

<127>
Wolfe, D.A.; Rice, T.R., Cycling of Elements in Estuaries., Fish. Bull., 70(3): 959-972(1972).

This review of the current (1958-1971) literature (17 references) on elemental cycling in the estuarine environment discusses the following facets: definition of elements under discussion; where major reservoir of elements, are (sediment, biota); transport of elements into and out of estuaries; factors influencing elemental transfer; and a directional out line of future research.
CYCLING; ESTUARY; REVIEW; BIOTA; ZINC; ARSENIC; CADMIUM; LEAD; MERCURY

<128>
Zitko, V.; Finlayson, B.J.; Wildish, D.J.; Anderson, J.M.; Kohler, A.C., Methylmercury in Freshwater and Marine Fishes in New Brunswick, in the Bay of Fundy, and on the Nova Scotia Banks., J. Fish. Res. Board Can., 28(9): 1285-1291 (1971).

Marine fish from 30 stations and freshwater fish from 16 stations were captured and stored frozen until analyzed. Muscle samples were vacuum dried and analyzed by gas chromatography. Results are presented for 17 freshwater and 30 marine species. With the exceptions of Atlantic wolffish and thorny skate all marine species analyzed contained less than 0.13 ppm methylmercury. Freshwater fish contained higher levels in general. Examples of methylmercury in fish expressed as mercury on a wet weight basis are: American eel, 0.07-2.08 ppm; chain pickerel, 0.27-1.58; white perch 0.75-1.07; yellow perch, 0.20-1.05; brooktrout, 0.08-1.13; and Atlantic salmon, 0.09-0.20
FISH; METHYLMERCURY; FRESHWATER; SHELLFISH